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EXISTING POLLUTION IN THE OHIO RIVER AND THE EFFECT OF CHANGES IN STREAM DISCHARGE BY THE PROPOSED FLOOD CONTROL PROGRAM ON THE OHIO RIVER WATERSHED

Public Health Service
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Office of Stream Sanitation
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Resume'.

EFFECT OF EXISTING POLLUTION ON THE OHIO RIVER.

During the summer months of low stream flow, when the navigation dams are in operation, to maintain navigable depths in the Ohio River, the main stream is composed of a series of some fifty pools through which the velocity is extremely low.

At such times sedimentation of sewage solids takes place in these pools to form sludge beds, in close proximity to the points where the sewers discharge.

Under these conditions the oxygen resources of the water are becoming exhausted and in the larger centers of population nuisance conditions are being approached due to the tendency toward septic conditions in the sludge deposits along the water front.

In and above Pittsburgh the river receives large quantities of acid drainage from abandoned and active coal mines. Acid drainage increases sedimentation in the Pittsburgh pools, resulting in the deposition of greater amounts of sewage solids than in the lower river, at present free from large quantities of acid drainage.

Acid drainage in the upper watershed has undoubtedly prevented nuisance conditions, especially at Pittsburgh, and probably at other points, where the diluting water available during the summer months would be insufficient to prevent nuisance conditions in a river not affected by acid drainage.

Thus in the summer during pool stage, low stream flow and high water temperatures, when biological activities are the greatest, the effect of sewage pollution is felt most at the community discharging it rather than at downstream points as is the case in a free-flowing river.

Although nuisance conditions do not actually exist at minimum flows at the present time in the centers of large population, the effects of pollution result in decreased recreational use of the stream and its immediate vicinity.

In the Pittsburgh area any considerable decrease in acid concentration or increase in sewage pollution will tend toward extremely offensive conditions resulting from septic action in the deposits, at present being inhibited by the concentration of acid.

At pool stages there are instances where, under special conditions, pollution from downstream points has moved upstream to affect the communities' own water supplies. These conditions have existed in the past at Cincinnati and Charleston, and may have existed at Marietta.

When sewage solids are being deposited near the sewer outlets and when times of flow from upstream sources of pollution are extremely long, allowing for natural stream purification, the water arrives at the water works intakes, usually located above the community, in exceptionally good sanitary condition, having a low bacterial content, the sewage materials largely changed by bacterial oxidation and the dissolved oxygen approaching saturation. Under such conditions the treatment of the water for the removal of the remaining sewage pollution is not difficult and the public health aspects of the effect of pollution on water supply not great.

When river velocities increase following periods of pool stage and when the navigation dams are lowered and the river flows in open channel, conditions with respect to the effect of pollution at water works intakes and along the water front at points of sewage discharge are exactly reversed.

As river velocities increase and the dams are lowered, the deposited material is scoured out and moved downstream, improving conditions along the water fronts of the larger communities where the amount of pollution is the largest, but transferring the effects of this pollution downstream to water works intakes where sewage pollution, from the public health aspect, produces its greatest effect in the Ohio River.

When scouring velocities are reached, the deposited sewage materials pass downstream in a series of waves of concentrated pollution, high in organic materials and with a maximum bacterial concentration. At such times the water treatment plants are greatly overtaxed and the factor of safety for which they were designed greatly reduced, because the amount of raw water pollution which the ordinary water treatment plant can be expected to remove is materially exceeded. It has only been by exceptionally expert operation that the quality of many of the water supplies along the river has been maintained.

In the past, it has been at times of the scouring out of deposited material, following long periods of pool stage, that intestinal disturbances have occurred along the Ohio River. Studies suggest the formation of intestinal irritants by chemical or bacterial action in the sewage solids in the pools, substances which are not removed by filtration nor indicated by the usual water analyses, in concentrations sufficient to affect a considerable proportion of the population using the river as a source of water supply.

In the upper watershed when the sewage deposits, in which biological action has been inhibited by high acid concentration, are flushed out, dilution decreases the inhibitive action of the acid and the effects of pollution are felt at downstream points over a considerable section of the upper river.

Following the effects of scour, the concentration of pollution, while decreasing somewhat at the various water works intakes, nevertheless remains high because, under open channel conditions, times of flow from upstream sources of pollution are decreased, decreasing the time in which natural stream purification agencies can operate, so that the degree of pollution is much higher than at pool stage. In many instances during unobstructed flow the limit of raw water pollution is exceeded at many of the water plants for a considerable percentage of the time.

Detailed information is lacking on many of the tributary streams as to the effect of existing pollution. However, many of the lower stretches of the larger tributaries are canalized and while population concentrations are much less in most instances than on the main river, the amount of diluting water for sewage disposal is also less. It is believed in general that the effect of pollution during low flow and pool stage and during open channel, as indicated along the main stream, will be very much the same on the tributary watercourses both in and outside of the zone of acid pollution.

To sum up briefly:

Present conditions in the Ohio River during low flows and pool stages result in a raw water of exceptionally good sanitary quality in the river above the various communities, where the water intakes are usually located, except that local downstream pollution may, under special conditions, affect the water intake on the river above.

Low flows at pool stage tend to localize the effects of sewage pollution along the water front of the community discharging it, because of sedimentation in the navigation pools to form sludge beds, the extent of the effect of pollution depending upon the degree of pollution and the diluting water available at the various points.

In zones of high acid concentration, the effects of sewage pollution are lessened near the points of discharge because of the inhibitive effect on bacteria.

Increases in run-off following pool stages improve conditions along the water front in the community discharging the sewage, but transfer the sewage pollution downstream to the water intakes located below.

Scour of deposited material produces a series of concentrated waves of pollution, which places a pollutional load on water treatment plants greatly in excess of that for which they were designed, making operation difficult and decreasing the factor of safety for considerable periods of time.

At the time of scour, soluble substances formed in the sewage deposits at pool stage, and not removed by filtration, may be present in concentrations sufficient to produce intestinal disturbances in a large proportion of the water users; conditions which have occurred in the past.

Following the cleansing of the stream by scour, the concentration of pollution decreases somewhat, but the velocities of flow at open channel are sufficient to convey rapidly the pollution from upstream sources before agencies of natural stream purification can operate, so that pollution effects are considerably greater during unobstructed flow than at pool stage.

Resume'.

EFFECT ON POLLUTION OF PROPOSED FLOOD CONTROL PROGRAM.

In the absence of definite information, it is assumed that the proposed flood control program on the Ohio River watershed will provide for the storage of excess water at times of high river stages, the impounded water to be released during the months of lower stream flow presumably in the summer following the period of spring run-off.

While no information is available as to the distribution of the excess water and its points of discharge, it seems very doubtful that flows sufficiently great could be maintained to shorten materially the times of pool stage that exist at present. In general therefore the effect on existing pollution in the Ohio River will result mainly from increases in low water discharge and consequently higher velocities through the navigation pools.

In the light of the available chemical and bacteriological data collected on the Ohio River, it is believed that increases in low water flow during pool stage would in general have the following effects on the existing pollution in the watercourse.

(a) An improvement in conditions along the water front of communities discharging pollution where septic conditions in the sludge beds formed were producing conditions tending toward nuisances, the extent of the improved conditions depending upon the amount of additional diluting water made available.

(b) A decrease in the concentration of bacterial pollution along the water front at the sewer outlets, the extent dependent upon the amounts of increased diluting water.

(c) A decrease in the concentration of acid, lessening its inhibitive action on the upper watershed, with the possible production of nuisances, in the Pittsburgh area and perhaps other areas, which do not exist at present.

(d) A transfer of the effects of pollution from the water front at the sewer outlets to points farther downstream, the distance below depending upon the amount of increased low water flow.

(e) The decrease in acid concentration in the upper river should remove its inhibitive action somewhat sooner than at present, the effects downstream remaining the same but the zone affected being somewhat different than at present.

(f) Increased summer run-off from certain tributaries near water intakes, under special conditions such as at Cincinnati where pollution from the Little Miami River is carried upstream to the water intake, might result in increased raw water pollution at some of the water treatment plants during pool stage.

(g) Any increased summer discharge will tend to shorten times of flow from upstream sources of pollution, increasing the effects of such pollution. The exceptionally low pollution of the raw water at the various intakes at present, under pool conditions, would tend to increase, the extent of the increase depending upon the increase in river velocities.

(h) Following periods of pool stage, there will still continue to affect water treatment plants the waves of concentrated organic and bacterial pollution as at present, with the attendant possibility of water-borne pathogenic organisms passing the already overloaded water treatment plants.

(i) Increased summer flows, if sufficiently great, might result in the dilution of possible intestinal irritants formed during the long periods of pool stage and tend to extend the time that the concentration of these substances would, under ordinary low water conditions, affect the water users.

(j) Those conditions which at present exist for a large part of the year, that is, a rather constant and heavy concentration of pollution at times of unobstructed flow and moderate run-off when pollution is carried rapidly to water intakes from upstream sources so that there is not sufficient time for natural stream purification agencies to act, will still continue to exist for a large part of the time in spite of the proposed flood control program.

From the lesser public health aspect of recreational use of the river and the preventing of nuisance conditions, the proposed flood control program, involving increased low water flows, would probably improve conditions in the immediate vicinity of many points of sewage discharge, with the possible exception that at places where acid drainage is at present preventing nuisances, increased flow might be detrimental; or where polluted tributaries enter close to water intakes, increased flow might increase the pollution in the raw water.

From the broader public health aspect of the effect of existing pollution on public water supplies in the Ohio Valley, it seems very doubtful if the proposed flood control program would materially affect present pollutional conditions at most of the water intakes which exist during a large part of the time, between low and moderately high river discharges, where a public health hazard already exists due to excessive pollution.

Rather than continue to depend upon the natural agencies of stream purification in the Ohio River, phenomena which are affected by acid conditions in many of the water-courses, and which seem to have reached a limit of usefulness for a large part of the time under existing conditions in the river, it would appear advisable to augment these natural agencies of purification by the construction of such sewage treatment devices which after proper investigation appear necessary and economical.

Report.

EFFECT OF PROPOSED FLOOD CONTROL PROGRAM
IN THE OHIO VALLEY
ON EXISTING RIVER POLLUTION.

The proposed flood control program in the Ohio Valley, as it will affect the present sanitary character of the watercourses, would appear to involve changed conditions in stream flow since the program contemplates the storage of excess flood flows at times of highest river stages and the release of the impounded water at times of relatively low stream discharge.

From the standpoint of public health, sewage pollution affects the river at times of low flow and pool stage because of the possible creation of nuisance conditions at the points of sewage discharge due to the deposition and possible fermentation of sewage materials. At such times, curtailed use of the river for recreational purposes has its public health aspect.

Of greatest importance however is the effect of pollution on public water supplies, which occurs, not at times of extremely low flow and pool stage, but at relatively high rates of discharge following pool stage, when deposits of sewage materials are flushed downstream and when times of flow are lessened from upstream sources of pollution, which limits the action of natural stream purification agencies.

In order to understand the existing sanitary conditions in the Ohio River due to the pollution now being discharged into it, which may be altered by the proposed flood control program on the watershed, there are presented: (I) a brief summary of existing conditions on the watershed in reference to population, sewered population, and population using the river as a source of water supply; (II) a summary of existing pollutional conditions in the Ohio River; and (III) a statement of the probable effect of the flood control program on pollution in various sections of the Ohio River.

(I) - The Ohio River - General.

The Ohio River and its tributaries drain an area of approximately 203,000 square miles. The watershed presents a widely diversified picture in topography, climate, population distribution, industrial and agricultural development.

During its 980 miles of flow from Pittsburgh, Pa., to Cairo, Ill., the Ohio River serves not only as a source of water supply for many of the communities and most of the industries, but also of necessity is the ultimate means of disposal for sewage and industrial wastes from the entire drainage area.

Construction by the Federal Government of some fifty navigation dams, completed in 1929, to maintain a channel having a minimum depth of 9 feet, has resulted in the river becoming a major artery of commerce for the communities bordering the main channel.

The population on the drainage basin of the Ohio River, based on the 1930 census estimates, was about 18.0 million, having increased in the past 15 years about 2.5 million, with apparently but little change in relative distribution.

Residing in close proximity to the main stream, in incorporated communities of 2,500 or over, there is an estimated urban population of about 3.9 million persons, including that in the Pittsburgh metropolitan area residing near the lower sections of the Allegheny and Monongahela Rivers which unite to form the Ohio at Pittsburgh.

The sewage from approximately 6.5 million people drains into the Ohio River either directly or through tributaries. Less than 30 per cent of this sewage is even partially treated.

At the same time it is estimated that nearly 2.5 million persons are at present dependent on the Ohio River as a source of public water supply, and that on the remainder of the watershed there are some 5.0 million persons in municipalities located on tributaries of the Ohio River dependent on water supplies from them, where many problems of water purification arise due to heavy sewage pollution of the streams.

During the past few years, growing difficulties have been experienced in obtaining water supplies of satisfactory quality from the river in the more polluted sections between Pittsburgh and Louisville.

Although this difficulty has doubtless been influenced by a complexity of factors, it appears to have been due very largely to progressive increases in sewered population, both along the main stream and tributaries, to a concurrent increase in the discharge of industrial wastes, and to canalization of the river as an aid to navigation.

Studies of the effect of sewage and industrial waste pollution on the Ohio River have been made from time to time during the past twenty-five years, as follows:

> In 1914 by the U.S.Public Health Service to determine conditions below several centers of population and to study natural stream purification phenomena.
>
> In 1929 and 1930 by the U.S.Public Health Service in the Cincinnati-Louisville section of the Ohio River to study the effects of complete canalization of the River and the changes since the 1914 study.

In 1932 by the Pittsburgh Metropolitan Drainage Commission. A limited amount of analytical data were obtained during a study in connection with the collection and disposal of the sewage from the Pittsburgh area.

In July and August, 1932, conditions in the Wheeling area were studied during a period of low stream flow and pool stage in the Ohio River, by the West Virginia State Department of Health.

For a considerable period in the past, daily bacteriological examinations have been made of the untreated Ohio River water at water filtration plants along the stream. These results have been summarized and tabulated by the filter plant operators and the State departments of health in order to have available a picture of changing conditions at the water purification plants supplying the various municipalities.

In spite of the several investigations of sanitary conditions in the Ohio River made in the past, the data are extremely limited from which to estimate present pollutional conditions, the changes which will occur in the future if remedial measures to abate pollution are not soon undertaken, and the probable effect of changed stream flow conditions which might result from the flood control program.

Increased population on the watershed and increased sewage and industrial wastes during the 23 years since the first federal investigation and complete canalization of the river, have made the analytical results collected at that time obsolete and practically unusable except as a record of past conditions. Later investigations have not been as extensive and do not cover periods of widely varying conditions in the river. No studies have ever been made in the most highly polluted sections of the river, namely the Ashland-Ironton area. Conditions on tributary streams are limited to a few samples at the mouths of the larger and more important ones, and very little is known of conditions on the remainder of the tributary watercourses. Discharge data at numerous points on the watershed are not always available and, where estimates have been made, may be subject to considerable error.

Probably the best available data representative of conditions over a considerable portion of the river are those collected at the water filtration plants as indicative of bacterial pollution along the river and the data collected in the Cincinnati and Louisville section during the extremely low water period of 1929-30, indicative of conditions during long periods of pool stage and decreased summer runoff, and probably applicable to other sections of the Ohio River.

(II) - Summary of Existing Pollutional Conditions in the Ohio River.

Based on the above available information, a summary of the effect of pollution in the Ohio River at the present time was prepared for the National Resources Committee during the special Drainage Basin Study in the summer of 1936. Present existing conditions, which may be modified by the proposed flood control program in the valley, may be summarized briefly as follows:

1. The general effects of canalization of the Ohio River, applicable to most communities along the stream, have resulted in: (a) the deposition of sewage and industrial waste solids near the sewer outlets during periods of low flow and pool stage; (b) decreased available dissolved oxygen and increased biochemical oxygen demand and at times the approach toward critical or nuisance conditions near the points of sewage discharge, due to sludge accumulations close to the community rather than at downstream points as usually occurs in streams with unobstructed flow; (c) increased organic and bacterial pollution in the pools along the water front where utilization for recreational purposes is the greatest, making its use for bathing dangerous and for other purposes at least extremely unpleasant; (d) the possible contamination of the community's own water supply due to currents and possible upstream flow in the pools, although the sources of pollution are at downstream points below the source of supply; (e) increased and often excessive pol-

lution at downstream points when the flows and velocities increase following pool stages, due to the scour of accumulated sludge and bacteria which travels as a series of concentrated waves down the river channel.

2. Acid conditions in the upper Ohio River cause coagulation and precipitation of suspended sewage and industrial waste solids in the pools through and below the Pittsburgh metropolitan area at times of low stream flow.

3. Sewage and industrial waste pollution in the upper Ohio River has reached the point where nuisance conditions undoubtedly would prevail during low flow periods if it were not for the inhibiting or retarding action of the acids present, which prevents bacterial decomposition of the sludge deposited on the stream bed behind the dams at such times.

4. The inhibiting action of acid in the water extends to varying distances downstream, depending upon a number of factors, but at times probably extends into the Ashland-Ironton area of the Ohio River.

5. Scouring and dilution of the deposited sewage materials with increasing run-off and velocities, results in a wave of highly polluted water which extends to varying distances downstream, depending upon river conditions, increasing enormously and during a short period of time the organic and bacterial pollution at downstream points.

6. Rapid changes in the character of the river water with increased flow following pool stage at Pittsburgh and communities below, when the wave of highly polluted water passes downstream, places an excessive bacterial load upon the water filtration plants along the river, in a relatively short time, requiring constant vigilance on the part of plant operators to meet changing conditions in raw water and to produce a suitable water supply conforming to the present standards of such domestic supplies.

7. While the organic and bacterial pollution of the river is excessive in the East Liverpool and Steubenville section of the river, due to pollution from the Pittsburgh area, the worst conditions as regards bacterial pollution of the river water used for domestic supplies occur in the Ashland-Ironton section of the river.

8. Insufficient data are available to determine whether conditions within the Ashland-Ironton area are a result of local pollution entirely or a combination of local pollution added to that from points above. It is believed that with relatively high stream flow conditions and decreased times of flow from upstream points, the pollution from the Pittsburgh area may, for varying lengths of time, affect the raw water as far downstream as the Ashland-Ironton area.

9. The upper section of the Ohio River is the most highly polluted bacterially of any stretch from which water supplies are taken. In order to produce water supplies safe for domestic use, all of the resources of modern water purification combined have had to be utilized. On the basis of normally expected efficiency, all of the water purification plants in this zone are now overburdened by excessive raw water pollution.

10. In the lower section of the river, although the Cincinnati, Louisville and Evansville water purification plants have not thus far experienced any degree of overloading comparable to that of plants further upstream, they have been overburdened occasionally in recent years, not only from a bacterial standpoint but also from heavy growths of filter-clogging organisms in the river. The present margin of safety at cities like Cincinnati and Louisville is relatively small, and appears to be growing less each year.

11. While the present margin of safety at such cities as Cincinnati and Louisville is becoming relatively small, efficient and constant supervision over filtration processes has up to now succeeded in producing a satisfactory water supply. In such communities as Aurora, below the pollution from Cincinnati, and New Albany, close to the pollution from

Louisville, the water plants are overburdened a large part of the time at present and it has been only by constant vigilance on the part of the available operating personnel that it has been possible to produce a safe domestic water supply at all times.

12. Outbreaks of gastroenteritis observed along the Ohio River, notably in 1930-31, apparently water-borne, at a time when the various water supplies met the present chemical and bacterial standards for a safe domestic supply, raises the question as to the importance and public health aspect of toxic chemical substances produced by bacterial or chemical action in the sludge accumulations during long periods of pool stage. If such substances are the result of changes in sludge deposits, and have the indicated effect, then the accumulations of organic deposits in water used as sources of water supply have a public health aspect not heretofore appreciated.

13. In addition to the public health aspects of pollution in the Ohio River, there are the economic aspects resulting from the deterioration of navigation structures, locks and dams, floating equipment, water supply and sewerage structures in the upper river as a result of acid and sewage pollution, difficult of estimation but undoubtedly

large, the losses due to the excess cost incurred in producing safe and suitable domestic and industrial water supplies from an excessively polluted river water, and the intangible but nevertheless present losses due to the restricted use of the water for recreational purposes.

(III) - Probable Effect on Existing Pollution of Flood Control Program.

The problem of determining changes in the effect of pollution, as outlined above, due to changes in stream flow resulting from the operation of the proposed flood control reservoirs is complicated on the Ohio River by lack of basic data, both chemical and bacteriological; insufficient hydrometric data; the presence of excessive amounts of acid drainage in the upper watershed; and by the operation of the navigation dams during the months of low stream flow to maintain a navigable channel along the main stream and on the lower stretches of some of the larger tributaries.

In contrast to the free-flowing watercourse, the navigation dams cause the deposition of sewage materials near the sewer outlets in the immediate vicinity of the sewered communities so that the effects of sewage pollution are observable along the water front rather than at points further downstream. With increasing flows, following pool stage, the navigation dams are lowered and the river flows unobstructed, at first carrying out the deposited material in a series of concentrated waves of pollution which changes very materially and in a relatively short time the character of the water to be treated in downstream filtration plants.

While the river is in a reasonably good sanitary condition above and in poor sanitary condition below major points of population concentration, at the time of low flow and pool stage, the effect on public health from the standpoint of the quality of water supply comes at a time when the river stage is relatively high and flowing rapidly. Under such conditions, times of flow from upstream sources of pollution are diminished and natural purification agencies have less time in which to operate.

In studying the changes in the effect of present pollution which might occur from decreased flood flows and increased low water flows as a result of the operation of the proposed flood control reservoirs, the analytical and hydrometric data of past sanitary surveys on the Ohio River have been utilized where possible, and in addition the experience gained from surveys of other watercourses and during experimental studies has been freely drawn upon to anticipate, in so far as possible, in spite of the complexity of the problem, the effect on existing pollution of the changed flow conditions.

To ascertain the effect of the proposed flood control program in the Ohio River valley on the pollution existing along the river as previously described, it would seem pertinent to study with the available data the following changed conditions in various sections of the river:

(A) Effect of increased low water flow on:
   (1) Acid drainage in the Pittsburgh area.
   (2) Tributary streams with acid drainage.
   (3) Conditions above and below communities on main stream outside the zone of acid drainage.
   (4) Conditions on tributary streams not receiving acid drainage.
   (5) Pollution at water works intakes.

(B) Effect of decreased run-off at extreme high water stages when the flood reservoirs would be in operation.

(A-1) - Effects of Increased Low Water Flows in Pittsburgh Area.

The 1914 report of the Public Health Service summarized conditions due to acid drainage in the upper Ohio River as follows:

"In the drainage area of the upper Ohio and more especially that of the Monongahela, the natural alkalinity of the run-off has been profoundly modified by acid wastes incident to the development of coal mining and of steel industries.

"Acid wastes result from coal mining when sulphides of iron, exposed during mining operations, become oxidized to sulphates, and on subsequent leaching are carried away in the drainage as acid solutions of ferrous salts. In the steel industry large quantities of sulphuric acid and, more rarely, of hydrochloric acid, are used for "pickling;" and the spent pickling liquors containing ferrous sulphate or chloride, with from one to three per cent of free acid, are usually discharged as waste, although in some plants ferrous sulphate is recovered as a by-product.

"The free acid and iron salts contained in these wastes, whether received from mine drainage or from pickling liquors, combine with the alkaline carbonates naturally present in the receiving waters, forming sulphates of calcium and magnesium, and when present in sufficient quantity leaving a residuum of unneutralized acid. The combination of alkaline carbonates and acid salts results in the formation of flocculent precipitates of iron compounds, with a resultant clarification of muddy waters which is very noticeable.

"Chief among the harmful effects of such acid pollution are increase in permanent hardness of the river waters and, where the acidity is not fully neutralized, the corrosion of iron and steel in boilers, in the hulls of vessels, and in submerged structures in dams. In the Monongahela and upper Ohio this corrosive effect is a matter of serious importance. The most striking biological effects of the acid pollution as observed in the Pittsburgh district in the course of this study (1914) are a reduction or elimination of certain forms of plankton, and an enormous reduction in sewage bacteria, to numbers far below what would be expected in waters subject to such heavy sewage pollution. This reduction in bacterial pollution is probably due in part to physical removal by coagulation and sedimentation, but also in part, and perhaps more largely, to direct inhibitory and bactericidal action."

The effect of acid drainage on the bacteria contributed to the upper Ohio River by the sewage from Pittsburgh and Wheeling, as compared with the bacterial pollution from Cincinnati and Louisville where acid conditions are not yet a factor, is indicated by the following tabulation (Table No. 1) which shows variations in the estimated daily per capita contribution of bacteria from these metropolitan areas.

TABLE NO. 1. ACTUAL NUMBERS OF BACTERIA, GELATIN AND AGAR COUNTS, AND B.COLI GROUPS, ADDED TO OHIO RIVER BY METROPOLITAN DISTRICTS OF PITTSBURGH, WHEELING, CINCINNATI AND LOUISVILLE, PER CAPITA OF SEWERED POPULATION. (From Public Health Bulletin No. 143).

Annual and Seasonal Averages.

Metropolitan Districts	Billions of Bacteria per Capita per Day								
	Gelatin Count			Agar Count			B. Coli Group		
	Jan. to Mar.	June to Oct.	Year	Jan. to Mar.	June to Oct.	Year	Jan. to Mar.	June to Oct.	Year
Pittsburgh Stations M-13 and A-7 to O-3 Pop. 710,500	383	108	-----	170	160	-----	31.7	3.6	-----
Wheeling Station O-88 to O-97 Pop. 59,500	-----	505	-----	-----	495	-----	-----	33.9	-----
Cincinnati Station O-461 to O-475 Pop. 494,300	3558	14102	11770	1003	18314	13356	119	583	-----
Louisville Station O-598 to O-619 Pop. 179,800	7359	13564	10841	907	15843	7963	193	391	-----

The ratio of per capita contributions of bacteria to sewered populations from the Cincinnati and Louisville districts, whether calculated on the basis of gelatin counts, agar counts or B.coli, are of the same order of magnitude; and may be considered in fairly close agreement. In the Pittsburgh and Wheeling districts the results are entirely different, the per capita contribution of bacteria from these districts being only a small fraction of that from Cincinnati and Louisville during corresponding seasonal periods. Thus during the months of June to October, the per capita bacterial pollution from the Pittsburgh district was consistently less than 1 per cent, and from the Wheeling district less than 5 per cent, of that from Cincinnati. In the winter months, January to March, when no data are available for Wheeling, the discrepancy between Pittsburgh and Cincinnati is reduced but is still very great, the per capita pollution from Pittsburgh being from 15 to 27 per cent of that from Cincinnati.

Had the pollution from the Pittsburgh metropolitan area borne the same ratio to population as at Cincinnati, the average agar count in the vicinity of Pittsburgh during the summer of 1914 would have been in the neighborhood of 1,000,000 instead of the observed count of less than 30,000 per cubic centimeter.

Decreased bacterial activity in the pools at Pittsburgh is reflected in the concentration of dissolved oxygen and the biochemical oxygen demand. Bacteria in their normal activities utilize dissolved oxygen to oxidize and stabilize organic matter, and with excessive amounts of such material present the available oxygen is completely depleted by bacterial action. The five-day biochemical oxygen demand is a measure of the organic material requiring oxygen for stabilization.

Assuming an estimated sewered population in the Pittsburgh metropolitan area of approximately 1.2 million persons, and not considering the effect of industrial wastes, one would expect an average oxygen demand during September, October and November, 1932, when the average river flows were 1,610, 2,940 and 18,900 second feet respectively, of about 35, 19 and 3 parts per million. The observed average from samples collected in the Pittsburgh area during these same three months when analytical data are available was 0.2, 0.9 and 2.6 parts per million. In the same months the average dissolved oxygen in the river was 3.0, 6.0 and 10.6 parts per million.

Assuming that the effect of industrial wastes in the Pittsburgh area was equivalent to that of the sewered population, the flow through the Pittsburgh area in September and October, 1932, would be equivalent to about 0.7 and 1.2 second feet per thousand population. Under normal conditions at Pittsburgh, without the effect of acid drainage, and with sedimentation taking place during pool stages, one would expect nuisance conditions to prevail during the summer months of high water temperatures, with this small amount of dilution water available.

In free-flowing streams the consensus of opinion seems to be that a dilution of from 3 to 6 cubic feet per 1,000 population is required to prevent nuisances and objectionable conditions from the discharge of sewage. In sluggish streams in which the water is already somewhat polluted, the discharge required for proper dilution may be as high as 10 to 15 cubic feet per 1,000 population.

In the accompanying tabulations of bacteriological and chemical data collected during the summer and fall of 1932, the latest information available, actual existing conditions in the upper river are indicated at varying rates of river discharge. Table No. 2 shows data for the Pittsburgh area on the basis of monthly averages for the lower sections of the Allegheny and Monongahela Rivers and at a number of points on the Ohio River below the Point Bridge in the

Pittsburgh area. Table No. 3 shows data for conditions in the lower Allegheny and Monongahela River and the Ohio River at Mile 3, below the Point Bridge, with variations in river discharge. Table No. 4 indicates conditions in the Wheeling area during July and August, 1932, on the basis of monthly averages of stream flow and chemical and bacteriological results.

TABLE NO. 2. MONTHLY AVERAGES OF COLI-AEROGENES INDEX PER 100 CUBIC CENTIMETERS; DISSOLVED OXYGEN AND FIVE-DAY BIOCHEMICAL OXYGEN DEMAND, 20° CENTIGRADE, PARTS PER MILLION; AT SAMPLING STATIONS ON THE ALLEGHENY AND MONONGAHELA RIVERS IN PITTSBURGH AND ON THE OHIO RIVER BELOW PITTSBURGH.

Month	Flow at Emsworth Sec. Ft.	A-13	M-6	Pa_3	Pa_{12}	Pa_{35}	Pa_{44}
Coli-aerogenes index per 100 cc.							
September	1,610	2,400	130	350	190	1,700	5,500
October	2,940	900	30	340	150	6,000	2,800
November	18,900	4,600	900	9,000	4,200	6,300	360
Dissolved Oxygen, parts per million							
September	1,610	6.8	5.2	0.8	5.3	7.4	7.6
October	2,940	8.5	7.2	4.9	7.0	8.5	8.9
November	18,900	11.4	10.6	10.9	10.4	11.3	11.3
Five-day biochemical oxygen demand, 20°C.							
September	1,610	0.1	0.5	0.2	0.3	0.4	0.6
October	2,940	0.5	0.5	1.2	0.5	0.6	0.9
November	18,900	1.9	1.6	3.1	2.1	2.0	1.6

A-13 Station 13 miles above mouth of Allegheny River.
M-6 Station 6 miles above mouth of Monongahela River.
Pa_3 Station 3 miles below Point Bridge, source of Ohio R.

TABLE NO. 3. VARIATIONS IN BACTERIOLOGICAL AND CHEMICAL CONSTITUENTS AT SAMPLING STATIONS IN THE PITTSBURGH AREA WITH CHANGES IN STREAM FLOW.

Range of flow	Average flow	pH	Dissolved Oxygen p.p.m.	B.O.D. 5-day p.p.m.	37° C. organisms per cc.	Coli-aerogenes index per 100 cc.
Allegheny River Station A-13						
0 - 1,000	930	4.9	6.9	0.1	650	2,030
1,000- 5,000	2,600	5.6	10.0	0.8	2,400	1,400
5,000-10,000	7,200	6.4	12.4	1.6	810	3,200
10,000-20,000	13,600	6.6	12.6	2.0	460	3,000
20,000-30,000	25,000	6.5	13.4	2.5	1,500	28,000
Monongahela River Station M-6						
0 - 1,000	440	3.8	5.6	0.4	250	80
1,000- 5,000	2,100	4.2	9.5	1.2	1,900	60
5,000-10,000	5,200	4.3	10.8	1.2	3,300	70
10,000-20,000	12,800	4.5	12.7	2.5	2,800	3,000
20,000-30,000	28,700	4.5	12.9	2.4	2,100	3,000
Ohio River Station Pa_3						
1,000- 2,000	1,500	4.4	0.7	0.3	920	300
2,000- 5,000	3,000	4.4	0.5	1.2	34,000	160
5,000-10,000	7,000	5.1	10.4	2.7	21,000	1,500
10,000-20,000	12,000	5.3	12.1	2.9	6,500	3,700
65,500	65,500	4.8	11.6	5.5	3,200	33,700

TABLE NO. 4. SUMMARY OF MONTHLY AVERAGES OF CHEMICAL AND BACTERIOLOGICAL RESULTS FROM SAMPLES COLLECTED FROM THE OHIO RIVER IN THE WHEELING AREA DURING JULY AND AUGUST, 1932.

Station, Mile (*)	Temperature, °C.	Dissolved Oxygen		5-day B.O.D. 20° C.	pH	Alkalinity, M. O.	Total iron	Bacteria	
		p.p.m.	Per cent sat'n					37° C. organisms per cc.	Coli-aerogenes organisms per 100 cc.
				July (11-31)					
62.0	26.3	7.3	89	0.8	5.9	13	0.35	280	380
74.0	26.5	7.0	86	.7	5.9	14	.31	1,100	4,700
88.8	26.9	7.0	87	.5	5.8	12	.32	1,800	1,600
96.2	26.8	6.9	85	.7	5.9	12	.07	2,300	3,700
109.8	26.8	6.9	85	.8	5.9	11	.04	740	520
				August					
62.0	25.3	7.8	94	0.6	6.3	12	0.04	980	110
74.0	25.8	7.2	87	.8	6.1	12	.13	1,100	2,000
88.8	25.9	7.3	89	.6	6.3	14	.20	1,900	3,100
96.2	25.8	6.8	82	.7	6.6	16	.08	6,700	20,000
109.8	25.9	6.9	84	.7	6.6	16	.12	2,300	1,700

(*) Miles below the head of the Ohio River (confluence of Allegheny and Monongahela Rivers at Point Bridge, Pittsburgh. Station 88.8 is above and Station 96.2 is below Wheeling, W.Va.

All of the data available for conditions in the upper Ohio River indicate that the concentration of acid is so great that bacterial action is inhibited and the ordinary and usual bacteriological changes are prevented from taking place, which in the absence of the acid and under present low water conditions would most certainly cause nuisances in the summer period.

The data further suggest that, with higher rates of stream flow, dilution of the acid takes place, resulting in more normal biological activities in the stream; and that biological activities are more normal even during low water conditions at points below the zone of excessive acid pollution as dilution occurs with inflow of tributary water.

On the basis of the data available relative to existing conditions in the Pittsburgh area due to sewage and industrial waste pollution, it seems very probable that increases in low water flow resulting from flood control would have the following effects:

Increases in flow sufficient to materially decrease acid concentration but insufficient to prevent sedimentation behind the navigation dams would increase materially the effect of sewage pollution in the river at Pittsburgh by lessening the inhibitive action of the acid drainage, permitting more nearly normal bacteriological action. The excessive amount of pollution and low discharge in the river would cause nuisances due to septic action in the deposited sewage materials in the months of decreased summer flow and high water temperatures, when the dissolved oxygen in the river would become entirely depleted.

If the increased low water flows were sufficient to prevent sedimentation in the pools at Pittsburgh, the organic load from pollution would move downstream and, with the inflow from lower tributaries, would cause such dilution of the acid that more normal pollutional conditions would prevail downstream from the metropolitan area. Dilution and decreased times of flow to downstream points would probably increase the effect of the Pittsburgh sewage at the various water works and extend its effects further downstream over a longer period of time than at present.

The only beneficial effect of sufficiently increased low water flow to prevent sedimentation in the Pittsburgh pools would result in a more uniform although perhaps heavier degree of bacterial and organic pollution in the water downstream but which might however be more easily handled in water treatment plants than the water at present with its rapidly changing degree of pollution resulting from alternate sedimentation and scour. Dilution of the acid drainage would be beneficial to the extent that the attack by the acid on navigation structures and other metals in the water would be decreased depending upon the amount of dilution effected.

(A-2) - Effects of Increased Low Water Flow in Tributaries Polluted with Acid Drainage.

While no detailed or extensive information is available relative to conditions on tributaries entering the Ohio River which receive acid drainage, it would appear possible to draw general broad conclusions as to the effects of increasing low water summer flows in tributary streams from the probable effects of such increase within the Pittsburgh area.

It seems reasonable to assume that in many of the tributaries of the upper Ohio River the degree of acid concentration has reached the point where normal bacterial activities of polluting substances have become inhibited as in the main stream and the actual effects of existing pollution greatly minimized.

As on the main channel, increases in low water flow will tend to dilute the acid drainage and the effects of any excessive pollution will be much more apparent. At the same time, increased low water flows will result in increased velocities and shorter times of flow between sources of pollution and downstream points, further increasing the effect of existing pollution. If the low water increase should be of such magnitude that actual dilution of pollution becomes a factor, then beneficial results should be apparent in the stream.

The effect on structures susceptible to attack by acid would be lessened as the dilution of the acid drainage increased.

(A-3) - Effect of Increased Low Water Flows on Conditions Above and Below Communities Outside Zone of Acid Drainage.

The probable effect of increases in low water flow within the Cincinnati-Louisville section of the Ohio River has been studied from the data collected in 1929-30 during a resurvey of this section of the river, by tabulating and plotting results of daily chemical analyses, dissolved oxygen, biochemical oxygen demand, expressed in parts per million, and the bacteriological determinations, coli-aerogenes organisms per 100 cubic centimeters, and the bacteria per cubic centimeter growing on agar at 37°C against the estimated stream flows on the same day of sample collection for analysis. Groups of points were then selected from which to determine averages of chemical and bacteriological results at a corresponding average river discharge. By this means it was hoped to study the trend of existing pollutional conditions in this section of the river as the low water flows increased, indicative of the probable effect of increased summer flows during pool stage in connection with the proposed flood control program.

The data collected during the more recent survey, in 1930, of sanitary conditions along the Ohio River between Cincinnati and Louisville, have been utilized to show conditions at the Cincinnati and Louisville water works intakes (Diagrams 1 to 3 and 7 to 9 inclusive), at a point below Cincinnati (Diagrams 4 to 6 inclusive), and at a point near the New Albany water works intake opposite Louisville (Diagrams 10 to 12 inclusive).

On the basis of these diagrams, changes in pollutional conditions with increasing low water flows, probably applicable to other stretches of the Ohio River not affected by acid drainage, may be summarized as follows:

(Diagrams Nos. 1 to 12)

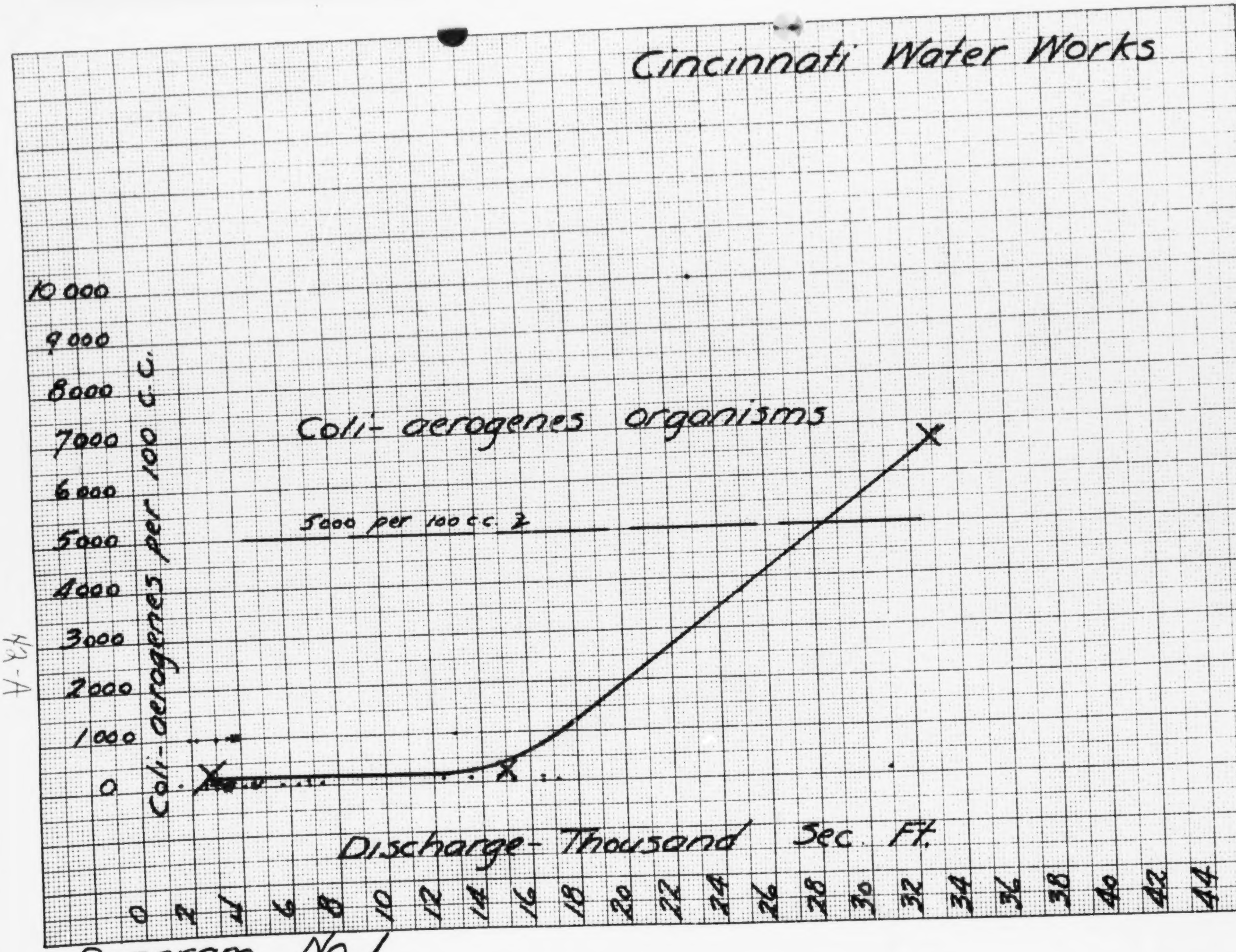

Cincinnati Water Works
Coli- aerogenes organisms
5000 per 100 c.c. Z
Coli- aerogenes per 100 c.c.
10 000
9 000
8000
7000
6 000
5000
4000
3000
2000
1000
0
Discharge- Thousand Sec. Ft.
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44

Diagram No. 1

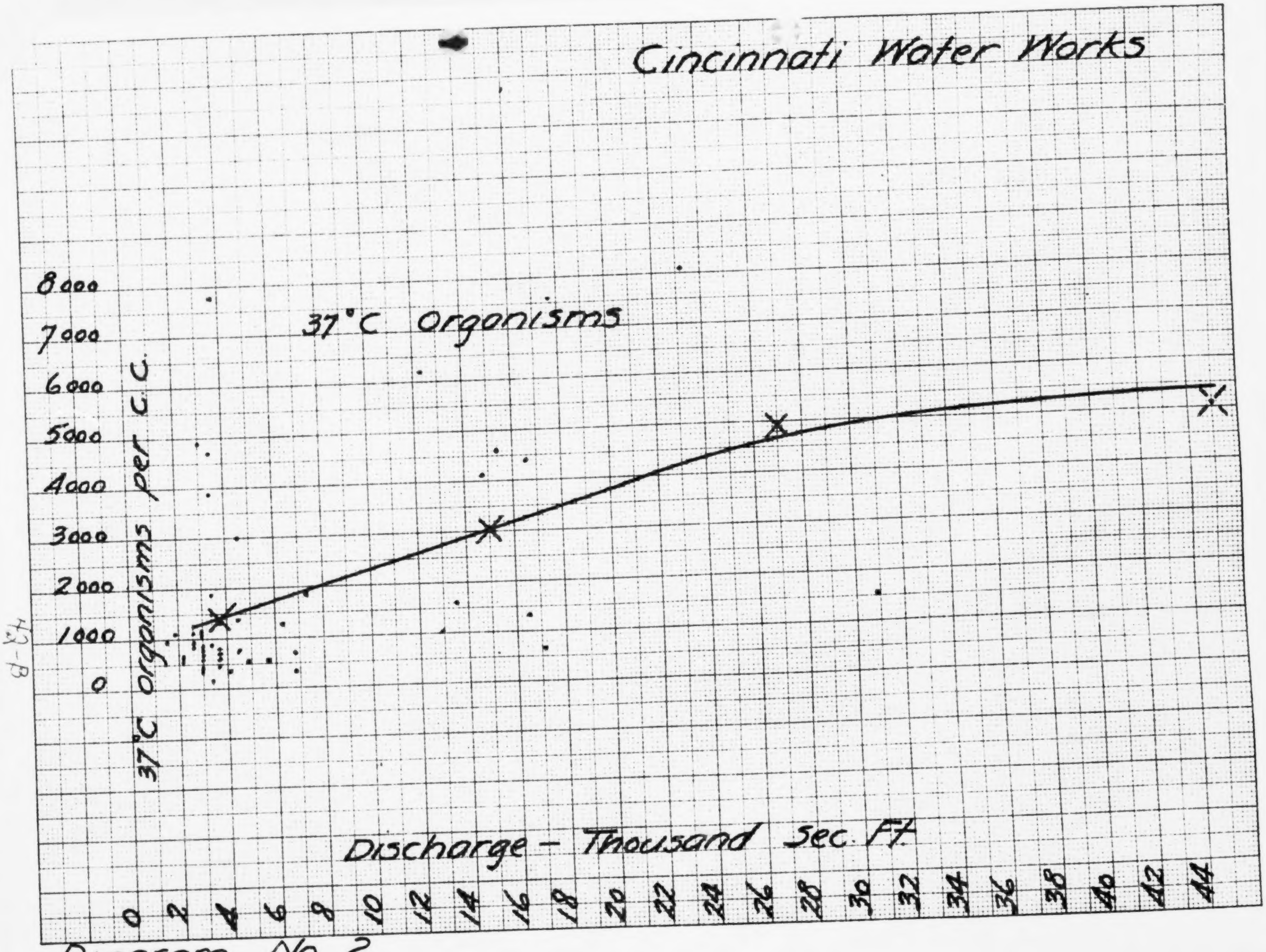

Cincinnati Water Works
37°C Organisms
37°C organisms per c.c.
8000
7000
6000
5000
4000
3000
2000
1000
0
Discharge – Thousand Sec. Ft.
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44

Diagram No. 2

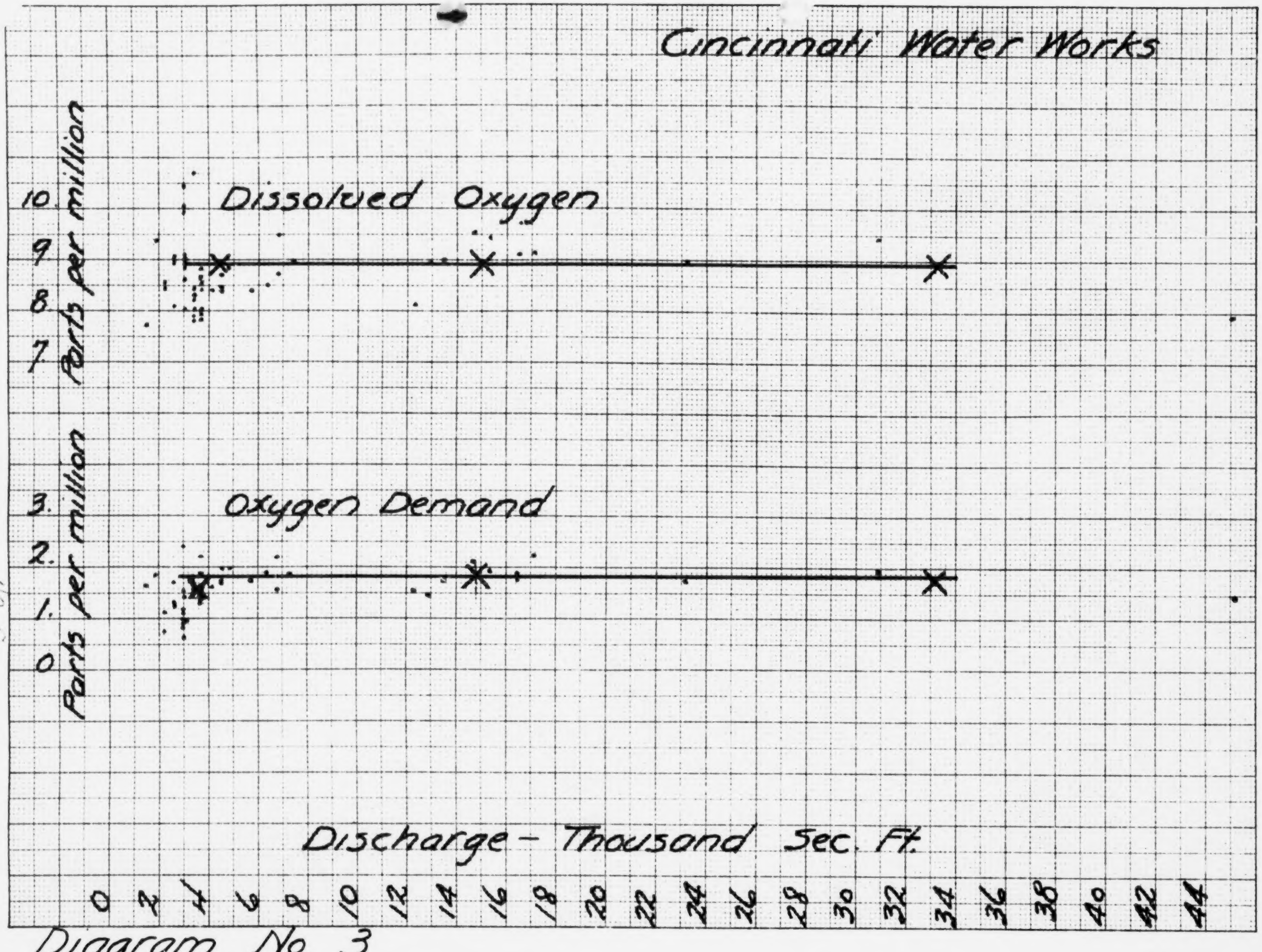


Diagram No. 3

42-C

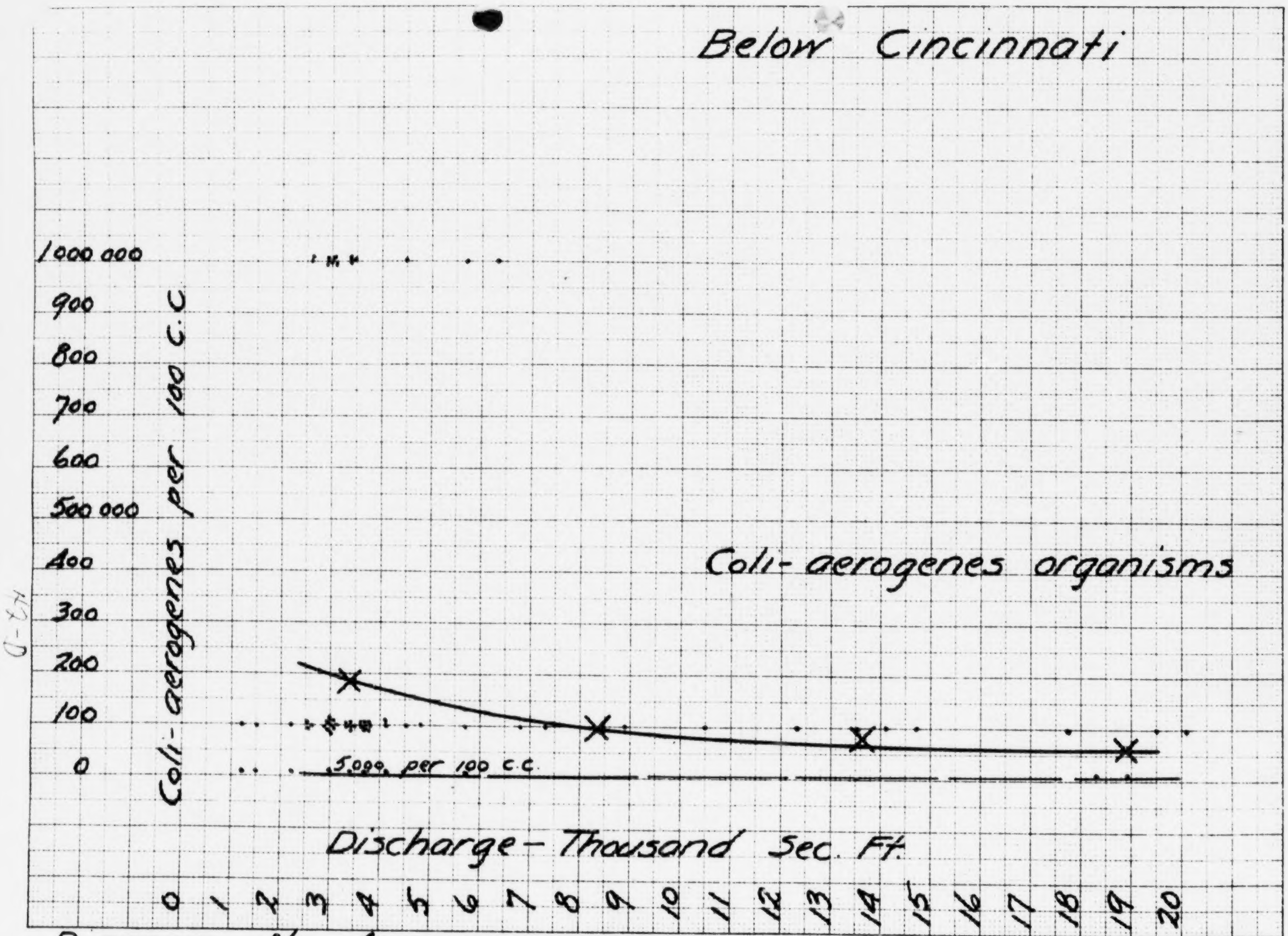


Diagram No. 4

H2-D

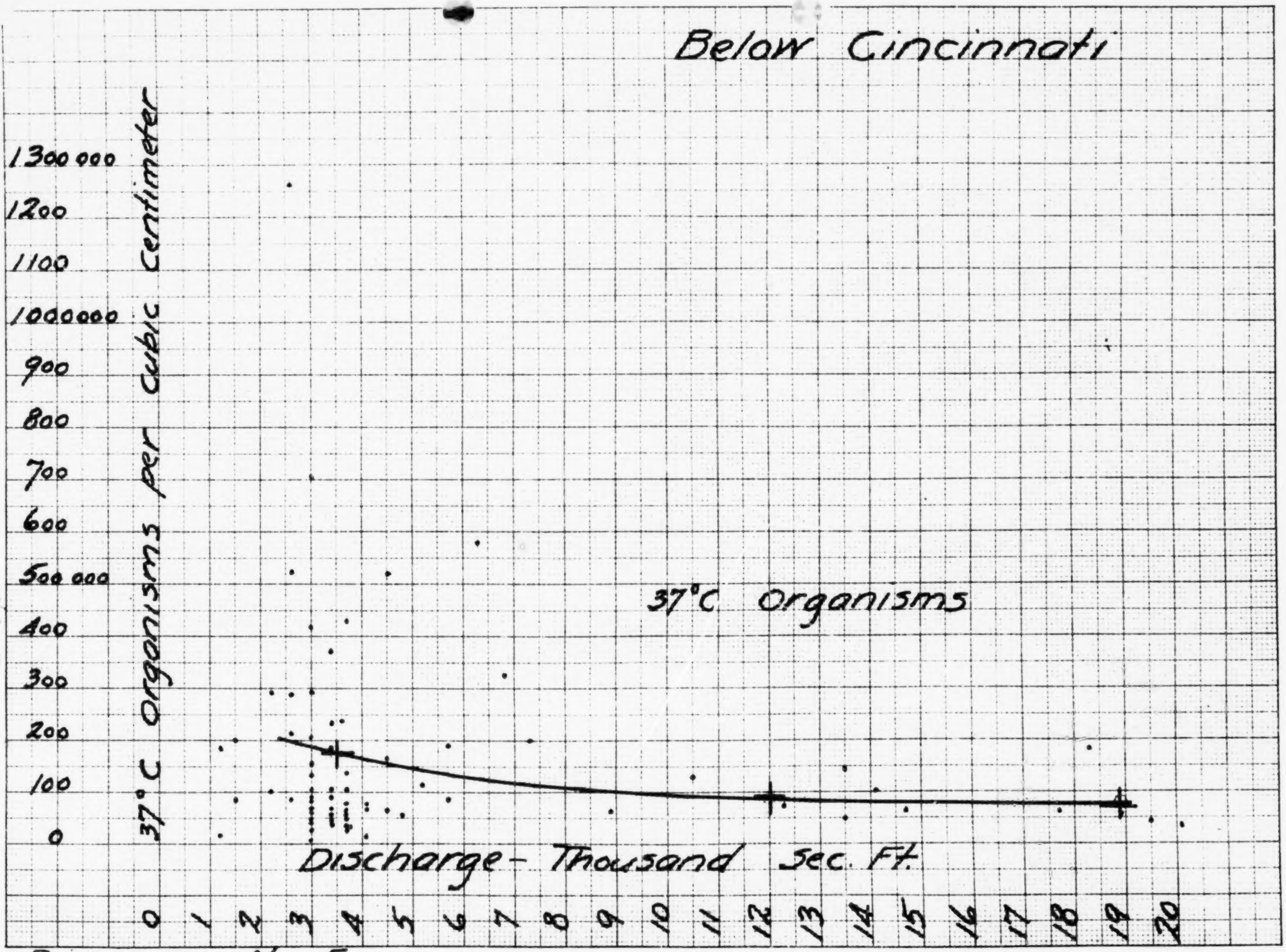

Below Cincinnati
37°C Organisms
37°C Organisms per Cubic Centimeter
1300 000
1200
1100
1000000
900
800
700
600
500 000
400
300
200
100
0
Discharge - Thousand Sec. Ft.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Diagram No. 5

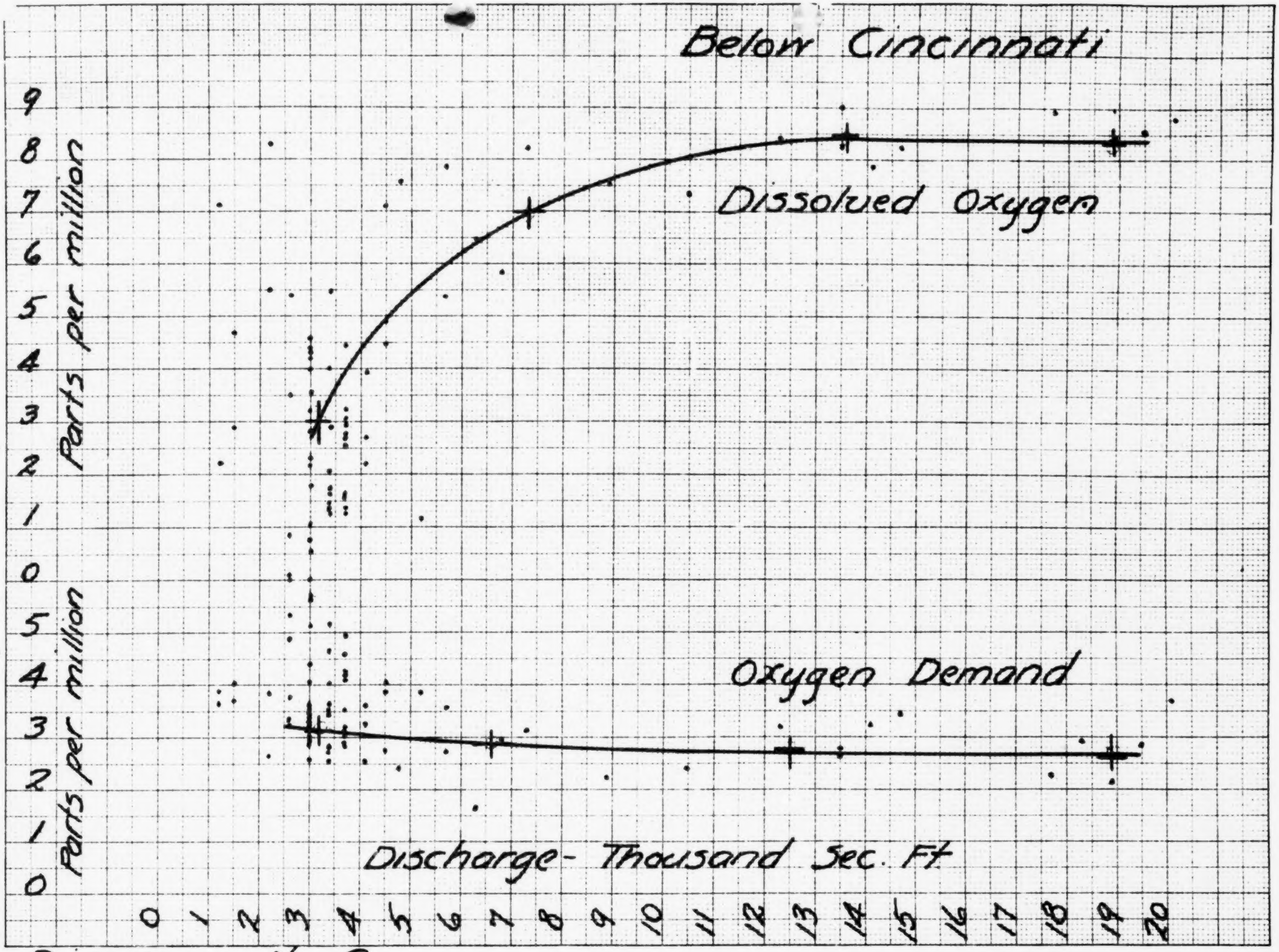


Diagram No. 6

42-F

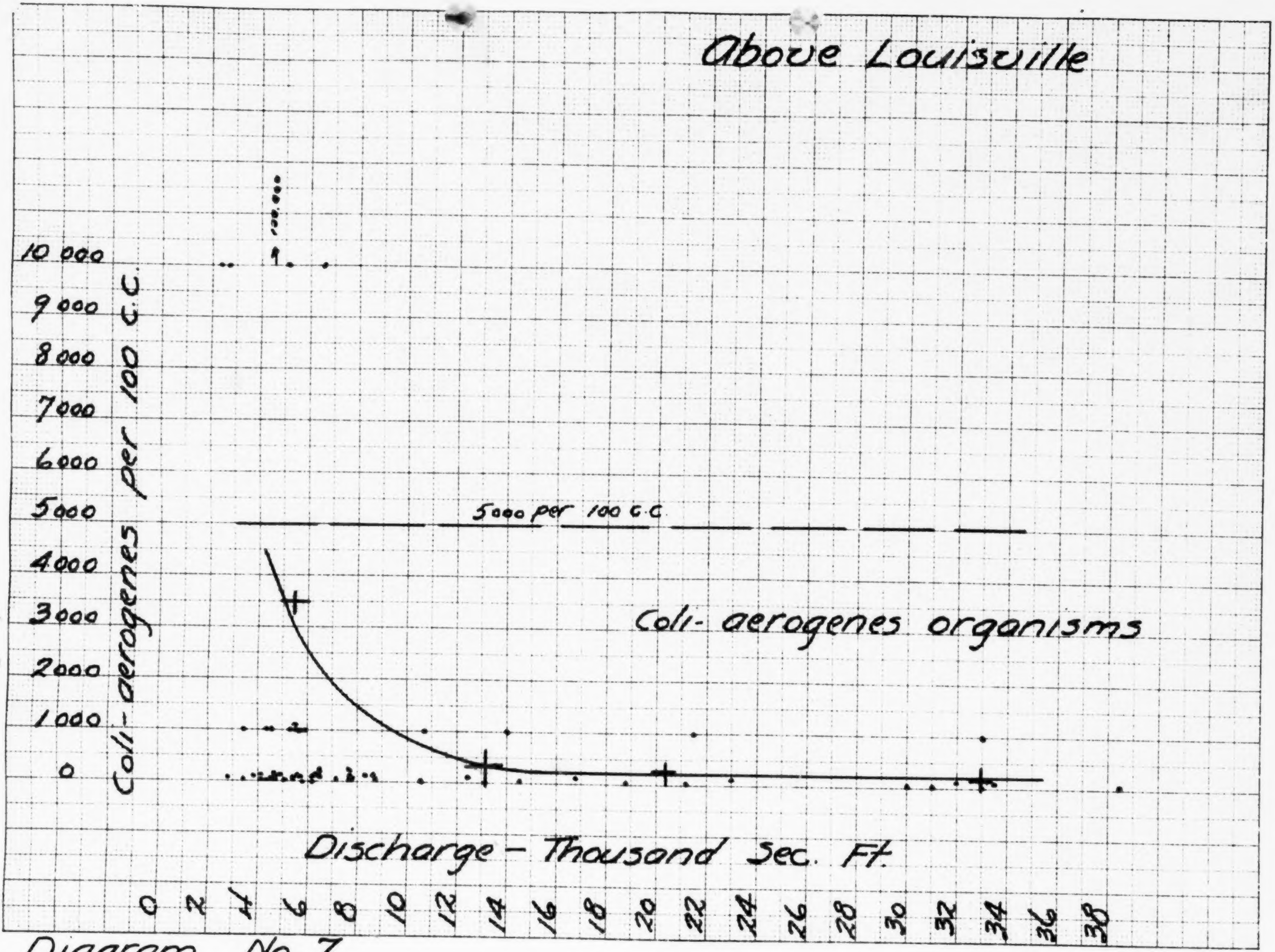

Above Louisville
10 000
9 000
8 000
7000
6000
5000
4000
3000
2000
1000
0
Coli-aerogenes per 100 C.C.
5000 per 100 C.C.
Coli-aerogenes organisms
Discharge - Thousand Sec. Ft.
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38

Diagram No. 7

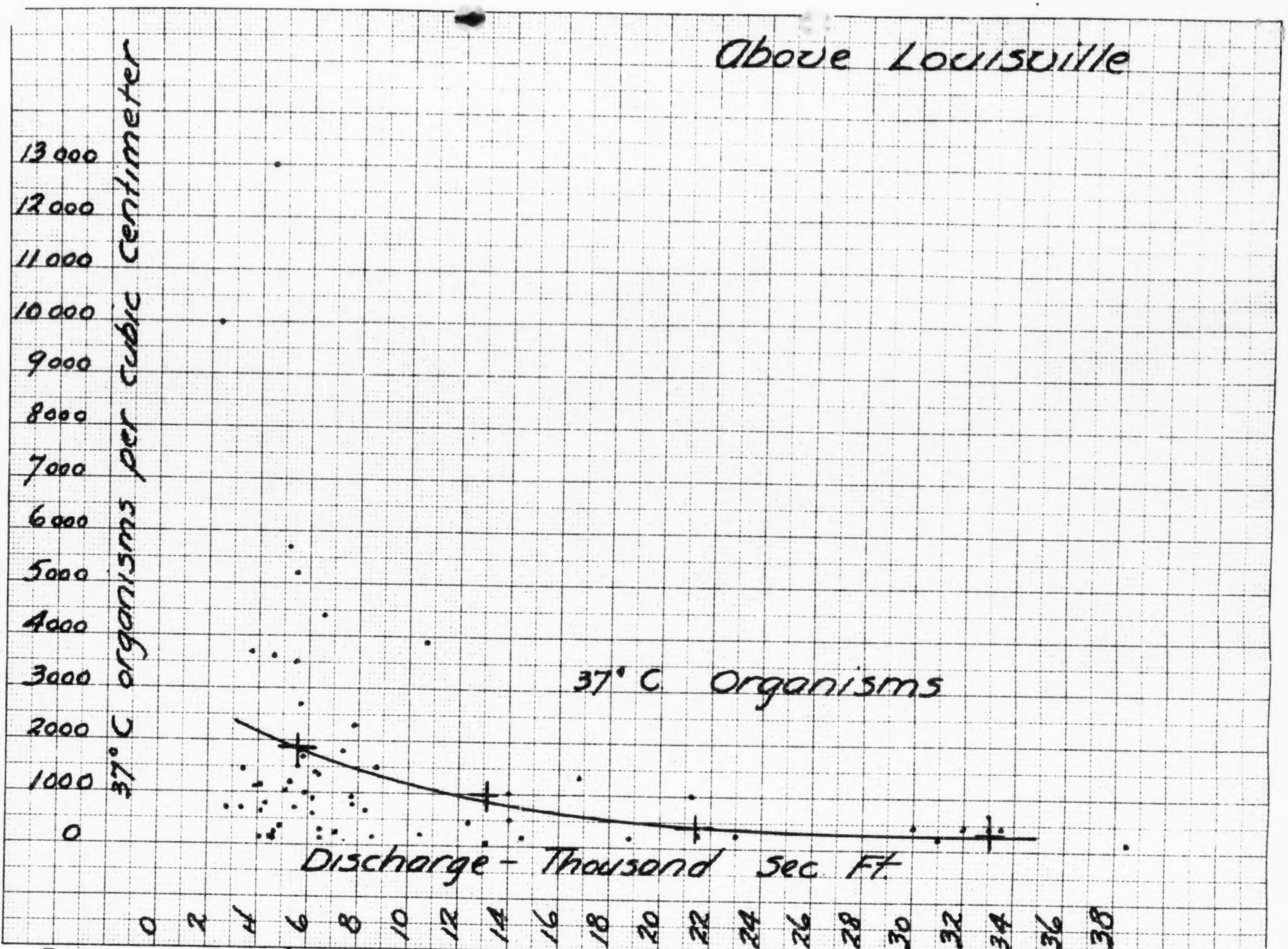


Diagram No 8

H-84

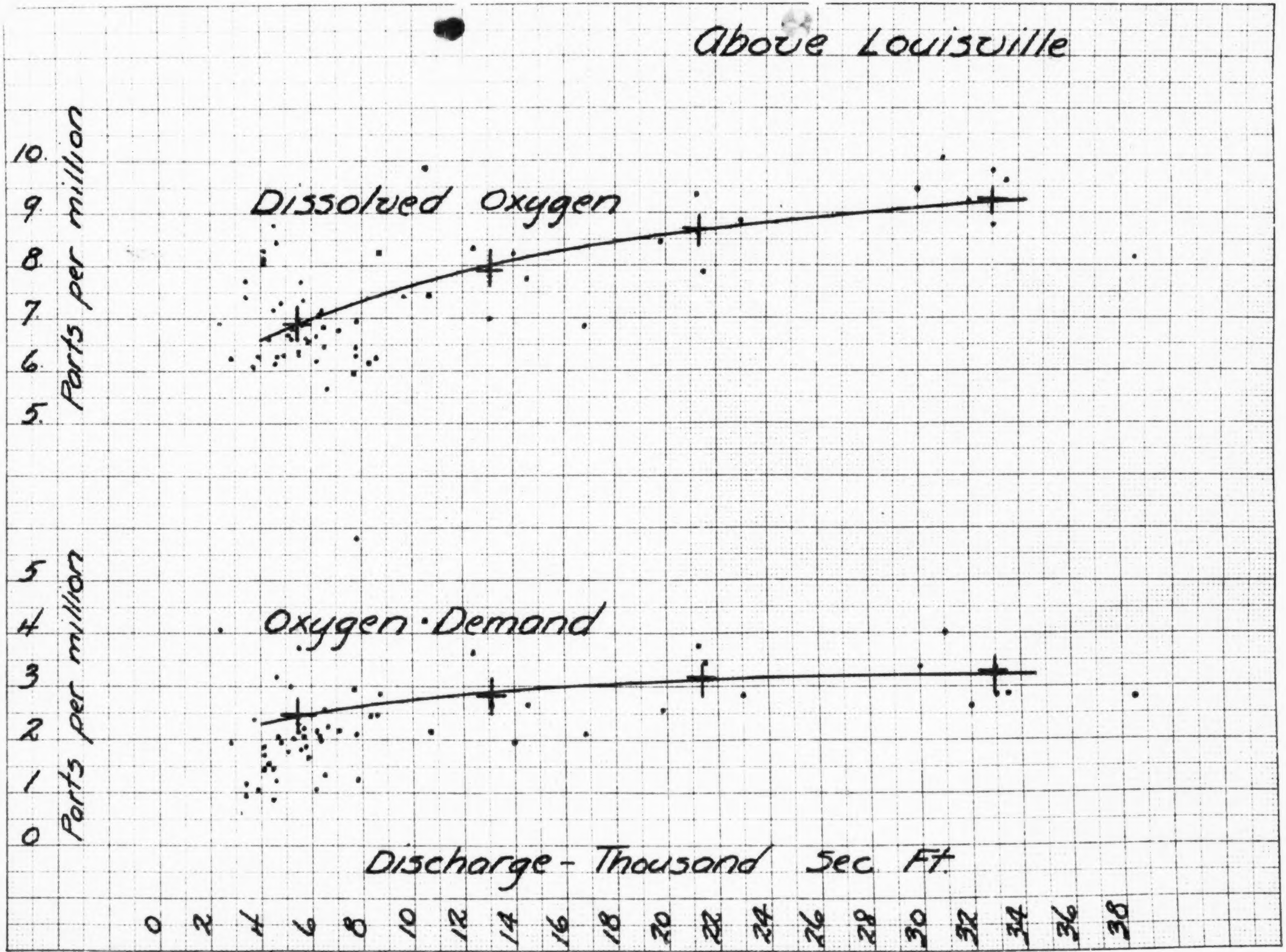

Above Louisville
Dissolved Oxygen
Parts per million
10
9
8
7
6
5
Oxygen · Demand
Parts per million
5
4
3
2
1
0
Discharge - Thousand Sec Ft.
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38

Diagram No. 9

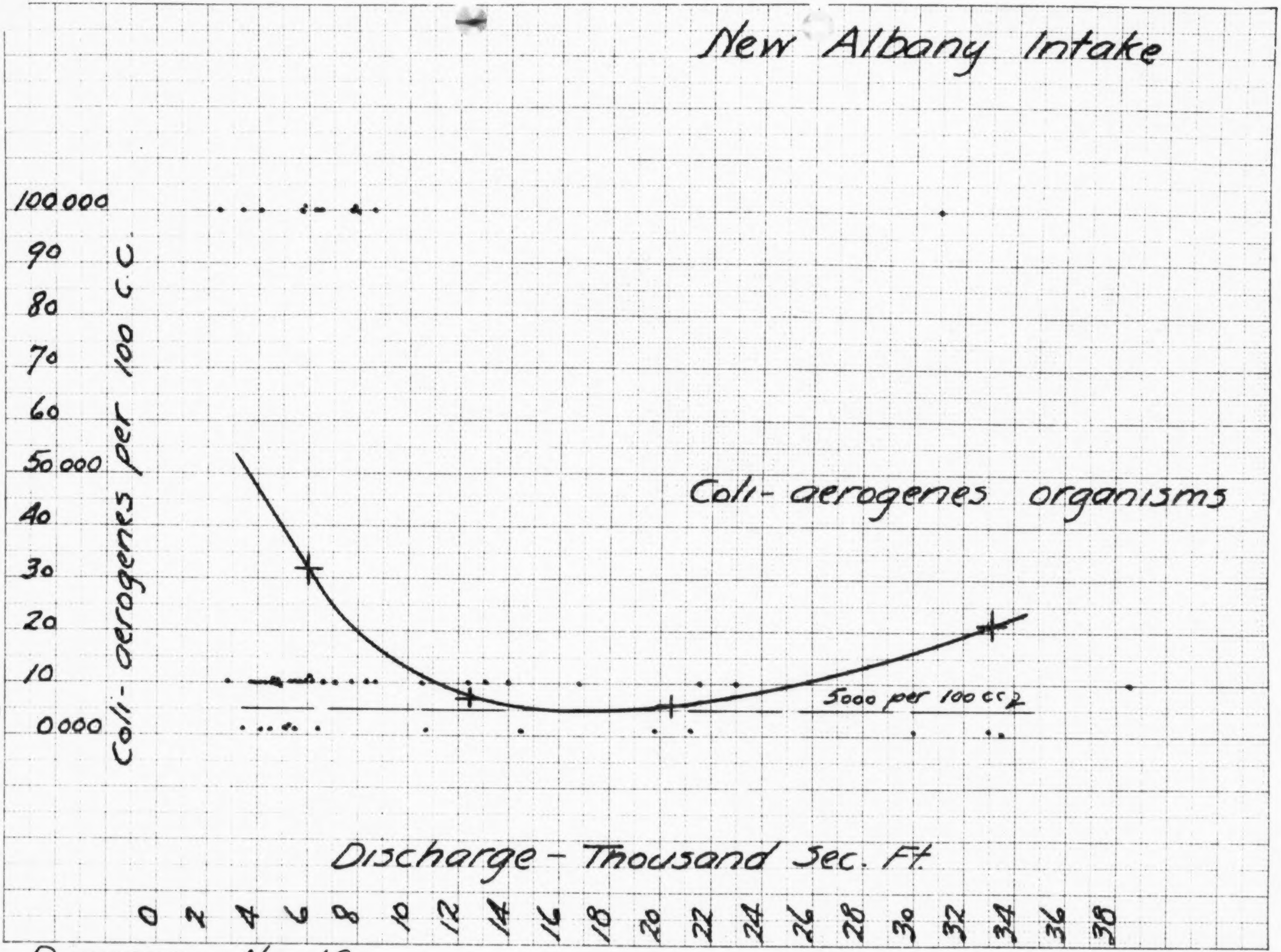


Diagram No. 10

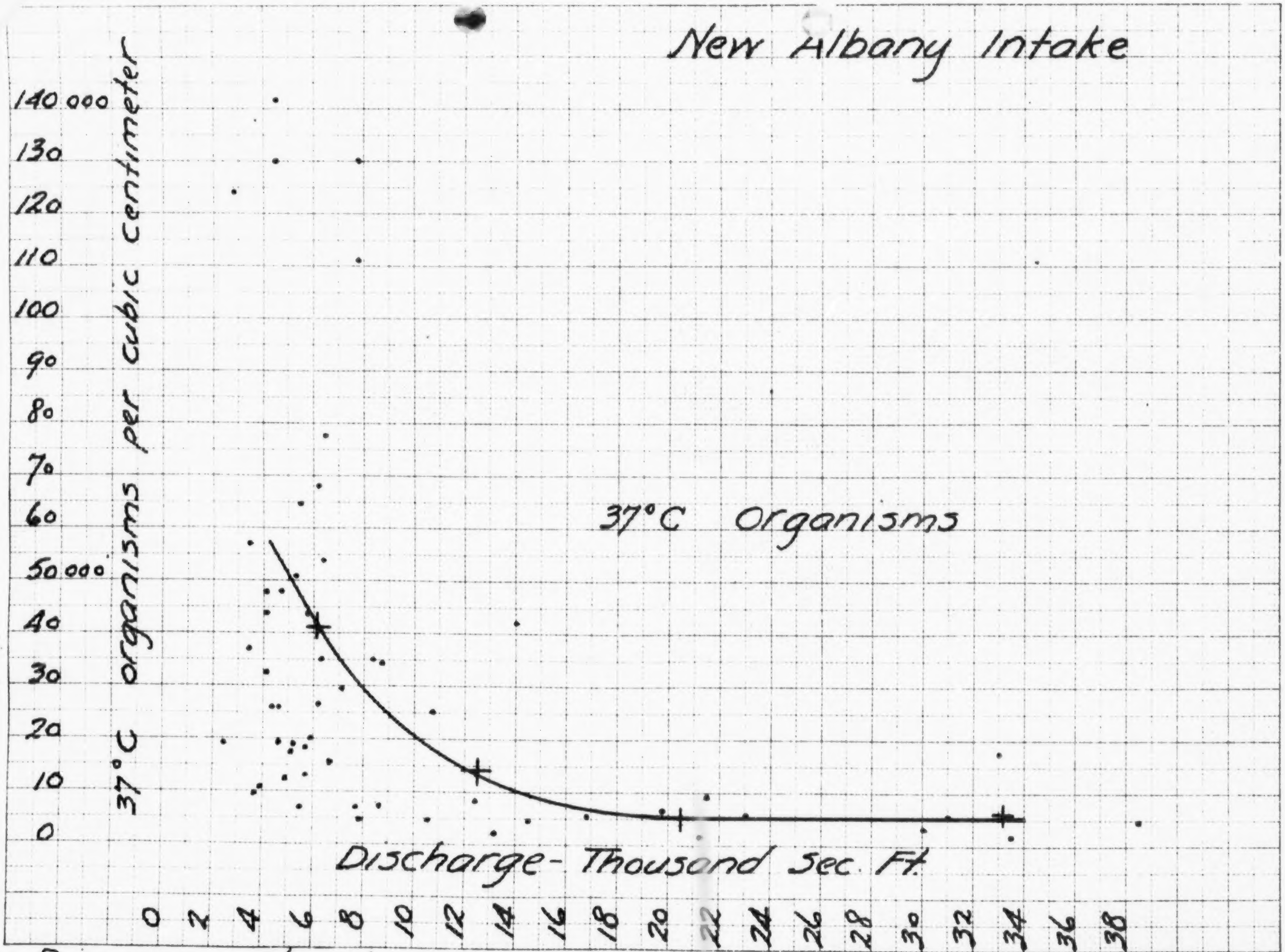


Diagram No. 11

42 K

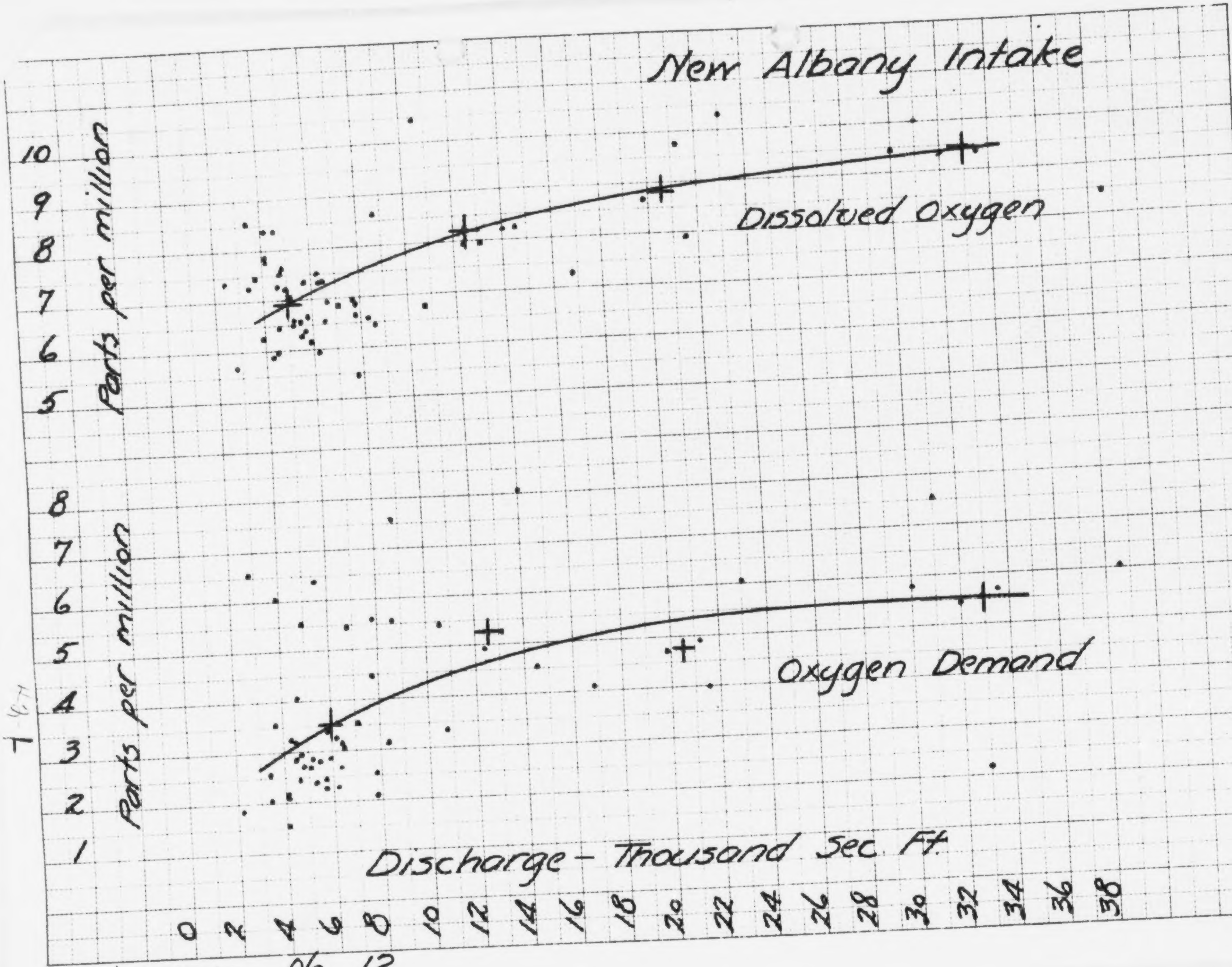


Diagram No. 12

Cincinnati Water Works

In the vicinity of the Cincinnati water works, above the city, at times of continuous pool stage and minimum discharge (about 2,500 second feet), Diagrams 1 to 3, inclusive, indicate an average dissolved oxygen content of about 9.0 parts per million, an average 5-day oxygen demand of slightly less than 2.0 parts per million, and coli-aerogenes organisms and bacteria growing at 37°C., averaging about 200 per 100 cubic centimeters and 1,300 per cubic centimeter respectively.

With increasing low water flows, the dissolved oxygen and oxygen demand appear to remain practically constant with flows up to 30,000 second feet. The average coli-aerogenes organisms also remain constant at about 200 per 100 cubic centimeters up to 14,000 second feet discharge, after which there are indications of an increase in numbers although the data for river conditions with flows in excess of 14,000 second feet are somewhat meager. Organisms growing at 37°C. appear to increase somewhat with increasing low water flows, reaching 3,000 per cubic centimeter at a discharge of 14,000 second feet and 5,000 per cubic centimeter with a discharge of 30,000 second feet.

The relatively good sanitary quality of the river water above Cincinnati, at low water flows and continuous pool stage, results from sedimentation in the pools above and the long times of flow from upstream sources of pollution during which natural processes of purification are in operation, eliminating to a large extent the effects of the pollution added to the river at points above.

The coli-aerogenes diagram indicates that with river discharges up to about 28,000 second feet the number of these organisms in the water is below the tentative U. S. Public Health Service raw water standard of 5,000 per 100 cubic centimeters for water that can be satisfactorily purified in the usual type of water filtration plant including chlorination.

Critical conditions in the river immediately above Cincinnati in the vicinity of the water works intake occur, not at times of pool stage and minimum discharge, but at times of relatively high stream flow when sewage solids are flushed from the upstream pools and when the time of flow from upstream sources of pollution is so short that natural agencies of purification do not have sufficient time in which to act.

The situation above Cincinnati may be summed up by stating that under summer conditions of low flow and pool stage, the water arrives above the city in the vicinity of the water works intake in such a relatively good sanitary condition that it seems impossible that any small amount of additional dilution would improve its condition to any great extent.

Below Cincinnati.

In Diagrams 4 to 6, inclusive, there are indicated conditions in the Ohio River below the sewer outlets of Cincinnati in the summer months of minimum run-off and continuous pool stage.

At minimum flows of about 2,500 second feet the average dissolved oxygen content appears to be about 1.5 parts per million, the oxygen demand slightly less than 4.0 parts per million, and the numbers of coli-aerogenes organisms and bacteria growing at 37°C. about 200,000 per 100 cubic centimeters and 200,000 per cubic centimeter respectively.

With increasing low water flows, there is an increase in the dissolved oxygen content from 1.5 parts per million at 2,500 second feet to 5.5 parts per million at 5,000 second feet, a decrease in oxygen demand of about 1.6 parts per million between flows of 2,500 and 5,000 second feet and a decrease in coli-aerogenes organisms from 200,000 per 100 cubic centimeters at a flow of 2,500 second feet to 150,000 per 100 cubic centimeters at a discharge of 5,000 second feet. A similar reduction in 37°C. organisms occurs between these two river discharges, a decrease from 200,000 bacteria per cubic centimeter at a discharge of 2,500 second feet to 150,000 per cubic centimeter at a discharge of 5,000 second feet.

Even with much greater increases in low water flows the bacterial pollution in the river below Cincinnati remains high, the coli-aerogenes count per 100 cubic centimeters apparently not falling below 60,000 with stream discharges up to 20,000 second feet. Also at flows up to 20,000 second feet, the organisms growing at 37°C. are always in excess of 70,000 per cubic centimeter.

The conditions on which the diagrams are based include the long period of continuous pool stage during May to October, 1930, inclusive, when there was but little manipulation of the navigation dams. Under ordinary summer conditions, when the dams are alternately raised and lowered, it is believed that on a number of days conditions in the river below Cincinnati would be much worse than indicated by the present data, because each time the navigation dam below Cincinnati is lowered the accumulation of sewage solids deposited during pool conditions is flushed downstream as the river velocities increase with increased discharge.

Below the zone of water of good sanitary quality above Cincinnati, near the water works intake, the discharge of sewage from the many sewer outlets along the water front within the city limits constantly increases the intensity of pollution until the zone of maximum effect is reached below the city. At pool stage and low river velocities, sewage solids are deposited in the vicinity of the outlets to form sludge banks which have a marked effect on the oxygen resources of the river and tend toward nuisances due to septic conditions as the dissolved oxygen approaches depletion.

It seems extremely doubtful if any small increase in low water flow would be sufficient to prevent the deposition of these sewage materials in the pools when the dams are raised, to keep the pools sufficiently clean to prevent scour as the stream flow increases after periods of pool stage.

Conditions below Cincinnati and to a large extent in the lower section of the pool above Dam No. 37 may be summed up by stating that the sanitary quality of the water is so poor during periods of low stream flow and pool stage that any slight increase in the amount of diluting water due to flood control operations would improve somewhat the sanitary quality of the water in the stream. It is believed, however, that the bacterial pollution in the water would still be excessive, would be objectionable for recreational uses, would be difficult to treat for use as a suitable source of domestic water supply for considerable distances below Cincinnati, and an approach toward nuisance conditions would still exist in the pool through the city.

Above Louisville

Data relative to river conditions above Louisville at times of low stream discharge and pool stage have been summarized in Diagrams 7 to 9 inclusive.

At minimum stream discharges of about 5,000 second feet, the average dissolved oxygen content of the water is approximately 7.0 parts per million, well toward the saturation point, and tends to increase as the low water flows increase, reaching over 9.0 parts per million when the river discharge reaches 34,000 second feet. There is a tendency for the oxygen demand to increase slightly between these rates of discharge from an average of about 2.5 to 3.2 parts per million. Decreases in the number of coli-aerogenes organisms and organisms growing at 37°C. are also indicated. Coli-aerogenes organisms decrease from about 3,500 per 100 cubic centimeters at an average flow of 5,000 second feet to 300 per 100 cubic centimeters at 14,000 second feet, after which the number apparently remains fairly constant up to flows of nearly 34,000 second feet. The decrease in 37°C. organisms is less marked because of lower initial numbers, the change ranging from 2,000 per cubic centimeter at a discharge of 5,000 second feet to about 500 per cubic centimeter at a discharge of 30,000 second feet.

Above Louisville the available data indicate that the coli-aerogenes count at low river discharges is probably always below the tentative raw water standard of the Public Health Service for waters that can be treated in the usual type of water filtration plant.

A comparison between the sanitary quality of the water above Cincinnati and Louisville indicates approximately similar conditions as to concentrations of dissolved oxygen, oxygen demand and 37°C. organisms, with the coli-aerogenes organisms at Louisville considerably in excess of the number at Cincinnati.

Difficulty from sewage pollution at the Louisville filtration plant, as at Cincinnati, does not usually occur at times of extremely low flow but at times of rather high discharge when the sewage from Cincinnati and other upstream communities is flushed downstream rapidly and reaches the Louisville intake without the benefit of sedimentation and before agencies of natural stream purification can operate to any great extent.

While an increase in low water flows above Louisville would tend to improve conditions, the critical conditions as regards pollution occur at much higher rates of discharge which would not be affected by low water control.

New Albany Intake - Opposite Louisville.

Conditions at the New Albany water works intake, indicated by Diagrams 10 to 12 inclusive, may not be entirely representative of the worst conditions at Louisville, due to the uncertainty of thorough mixing of the sewage in the river section and to the fact that the sampling station is located above a number of the sewers discharging into the river from the Louisville metropolitan area.

The data show average dissolved oxygen content at minimum stream discharge of 6.5 parts per million, oxygen demand of 3.5 parts per million, coli-aerogenes count of 40,000 per 100 cubic centimeters, and 37°C. organisms 50,000 per cubic centimeter.

In comparison with conditions below Cincinnati the degree of pollution at Louisville is considerably less, the oxygen demand lower, the dissolved oxygen higher, and the bacterial concentration approximately one-fifth as much as at Cincinnati, due to some extent at least to a smaller amount of pollution being discharged into a larger volume of water.

With increasing volumes of low water flow past Louisville, the dissolved oxygen tends to increase from 7.0 to 9.5 parts per million, at a flow of 34,000 second feet, the oxygen demand increases slightly from 3.5 to 5.5 parts per million, and the bacterial concentration decreases, the coli-aerogenes organisms from about 50,000 to 5,000 per 100 cubic centimeters, and the 37°C. organisms from 50,000 to 5,000 per cubic centimeter. The average coli-aerogenes concentration at relatively low flows appears not to fall much below the tentative standard for raw waters from which satisfactory domestic supplies can be produced by filtration.

As at points below Cincinnati, increasing low water flows at Louisville have a tendency to improve the sanitary quality of the water until the volume of flow reaches the stage where scour occurs in the upstream pools, bringing waves of highly polluted water past the city, natural purification not having had time in which to operate. At such times the intensity of low water pollution is materially exceeded.

The included diagrams are based on pollutional conditions as of the summer of 1930. In the subsequent seven years, both the population and sewage pollution have increased, so that at the present time the degree of pollution is proportionately greater than in 1930. With future normal increases in population and sewage contamination, pollutional conditions will be still further intensified so that in all probability the beneficial effects of increased low water flow below major sources of pollution will become proportionately less as the sewage load increases.

It therefore seems reasonable to conclude that the slight increase in low water flows will have but little effect on the sanitary quality of the water of the Ohio River, at least in the Cincinnati-Louisville area, since the critical conditions do not prevail during such low water periods but at times when the discharge is comparatively high causing scour and decreased times of flow from upstream sources of pollution, eliminating the effect of natural stream purification processes.

On the basis of the interpretation of the available data in the Cincinnati-Louisville section of the Ohio River, the results of which are believed applicable to other communities on the main stream outside the zone of acid pollution, increases in low water flows would change existing conditions somewhat as follows:

Above communities on the main stream, the combined effects of pool stage and low flow, causing sedimentation and long times of flow from upstream sources of pollution during which processes of natural stream purification are operative, result in producing a water of relatively good sanitary quality at the water intakes above the cities. Any increase in low water flow would in general tend to increase the effect of upstream pollution by decreasing times of flow, and the increase in the effect of the pollution would become greater as the low water flows increased.

The maximum effects of the present pollution discharged into the Ohio River occur above the cities, where the water intakes are usually located, at times when there is a rate of discharge considerably above the minimum and particularly as the flows increase after a period of pool stage when settled sewage materials accumulated behind the dams are flushed downstream during a relatively short-time-of-flow period. The operation of the flood control reservoirs would in no way remedy pollutional conditions due to the above flow conditions.

Through and immediately below communities on the main stream, the effects of local pollution contributed to the river during pool stage and low flow are in large degree dependent on the amount of pollution discharged and the diluting water available. When the river is at pool stage, deposition of sewage solids undoubtedly takes place near the sewer outlets and these sludge beds exert a tremendous effect on the oxygen resources of the water which if depleted may result in odors and unsightly appearance of the stream. Such conditions along the water front within the city make it, if not actually dangerous for recreational purposes, at least extremely unpleasant. Any increase in low water flow providing additional dilution and supplying increased dissolved oxygen to the water along the stretch of sewage discharge would be beneficial to existing pollutional conditions.

The greatest effect from local sources of pollution at pool stage and low water flow is of course below the community and along a river stretch representing several hours' flow below the lower sewer outlets. The extent of the effect of this pollution is dependent on amount of pollution and dilution available.

Below communities such as Cincinnati, Ashland, Ironton and Portsmouth, where the effects of sewage pollution during low flow is a maximum, any increase in minimum summer flow should be beneficial to the stream and decrease the effects of pollution, the extent of the decrease in effect depending upon the amount of additional flow.

On the other hand, material increase in low water flow, while beneficial at and immediately below these communities, will move the pollution downstream and increase the pollution at lower water works intakes if the time of flow is so reduced that natural purification agencies do not have time in which to operate. Flows sufficiently great to prevent the deposition of sewage materials along the water front would undoubtedly improve local conditions but would increase the pollution over a greater river stretch downstream.

In brief, then, it seems fair to assume that increases in low water flow would have but little beneficial effect on the sanitary quality of the water at the several water works intakes located above points of major population concentration but might be detrimental by decreasing times for natural purification in the stream. Since the worst conditions occur at the intakes with relatively high flows, the flood control program would in no way help such conditions in the raw water supply. Along the water front and immediately below the large centers of population, increased low water flow would be beneficial in decreasing the effects of local pollution. In some instances the increase in low water flow would have to be considerable to reduce materially the highly contaminated condition of the river due to the discharge of sewage from several hundred thousand persons.

(A-4) - Effect of Increased Low Water Flow on Tributary Streams Not Affected by Acid Drainage.

On the tributary streams not affected by acid drainage, whether canalized for navigation or not, the increased dilution resulting from increases in low water flow should be beneficial to the stream at and immediately below points of pollution. Additional discharge, increasing velocities and decreasing times of flow, would increase the effects of pollution at downstream points by shortening times of flow and decreasing periods in which natural purification agencies can operate.

Under certain conditions the addition of diluting water to a sewage-polluted stream results not in a diminution of bacterial pollution but an increase due, it is believed, to a change in the biological balance which for varying periods permits multiplication of the sewage bacteria. Phenomena of this type have been observed in the Ohio River below the Great Miami, in the Illinois River below the Kankakee, and in the Mississippi below the Chippewa.

In some circumstances, therefore, it might be possible that dilution from increased low water flows combined with decreased times of flow would both act for detrimental conditions at downstream points rather than as balancing factors.

(A-5) - Effect of Increased Low Water Flow on the Pollution at Water Works Intakes.

From the public health aspect, the greatest effect of present pollution in the Ohio River is on the public water supplies derived from it. It is estimated that nearly 2.5 million persons are at present dependent on the main stream as a source of public water supply where many problems of water purification arise due to the heavy pollution of the stream by sewage and industrial wastes which affect the quality of the water used for domestic consumption, which in turn has a direct effect on the health of the large population using such sources of supply.

Daily results of the bacterial quality of the untreated Ohio River water have been made available from the records of filtration plant operators, supplemented by records in the various State health agencies, at the following places located on the river at the indicated distances below Pittsburgh:

East Liverpool, Ohio,	Mile	43.5
Steubenville, Ohio,	"	68.0
Wheeling, W. Va.	"	90.0
Marietta, Ohio,	"	172.0
Huntington, W. Va.,	"	308.3
Ashland, Ky.,	"	322.6
Ironton, Ohio,	"	327.2
Portsmouth, Ohio,	"	356.0
Cincinnati, Ohio,	"	470.2
Louisville, Ky.,	"	603.7

The maximum degree of raw water pollution in the Ohio River as measured by the coli-aerogenes index, consistent with the production of filter plant effluents, by the usual methods of water treatment including chlorination, which conform to the revised U. S. Treasury Department standard (about 1 coli-aerogenes group organism per 100 cubic centimeters) is approximately 5,000 per 100 cubic centimeters.

This raw-water maximum is a mean condition, defining the limiting degree of raw water pollution which the average plant of the type studied might be expected to tolerate consistent with attaining the objective stated under normal conditions. Some individual plants, particularly those containing highly elaborated features, such as double-stage sedimentation or double filtration, would be expected, on the basis of the observations, to purify successfully raw waters more highly polluted than above indicated. Others. less highly elaborated or skilfully operated, might be unable to meet the raw water condition.

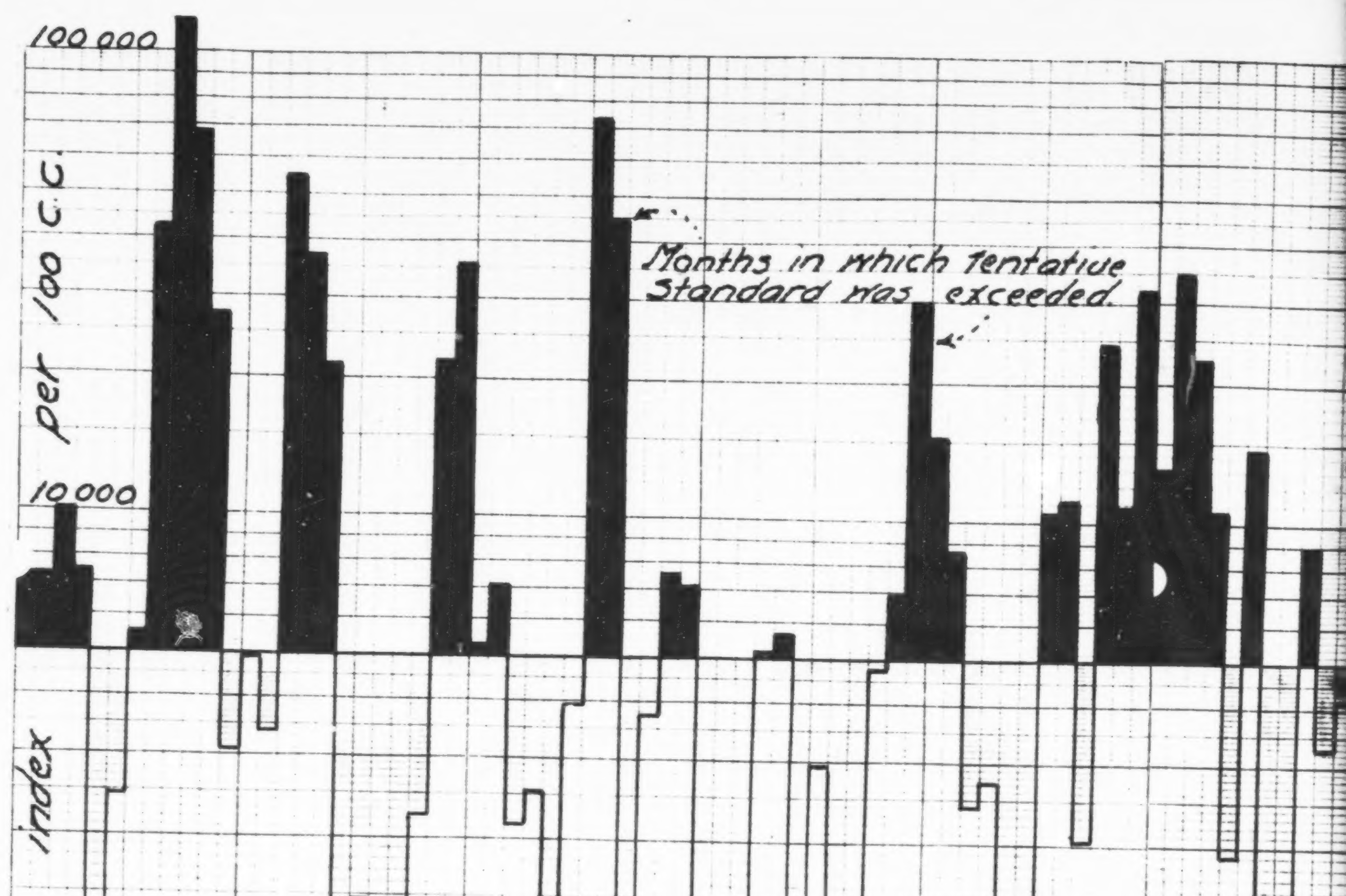
In the following tabulations and diagrams, the results of the bacteriological determinations of untreated river water at filtration plants on the Ohio River, expressed as the average monthly coli-aerogenes index per 100 cubic centimeters during the 10-year period 1926-1935, have been shown as follows:

(1) A series of diagrams, Nos. 13 to 22, indicating graphically, for each of the filtration plants, the average monthly coli-aerogenes index per 100 cubic centimeters during the 10-year period 1926-1935 in relation to the tentative raw water standard of 5,000 coli-aerogenes organisms per 100 cubic centimeters.

(2) A tabulation based on the above data, showing for each filtration plant the percentage of the time that the tentative raw water standard of 5,000 per 100 cubic centimeters was exceeded, and the percentage of the time during the 10-year period 1926-1935 in which the average monthly index was between certain designated limits.

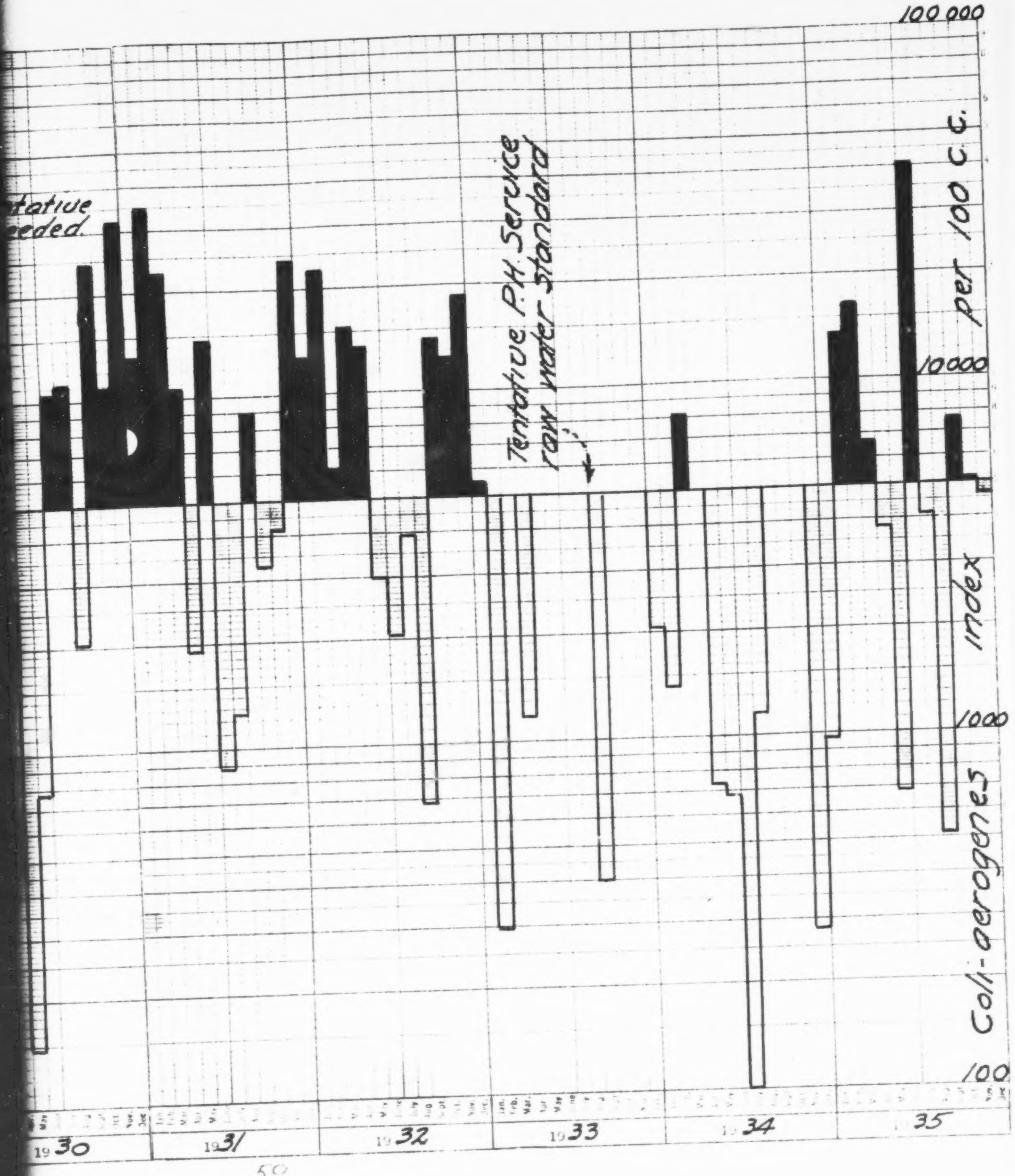
(3) A diagram based on the above tabulation showing graphically the percentage of the time that the tentative raw water standard was exceeded at the several water filtration plants along the river.

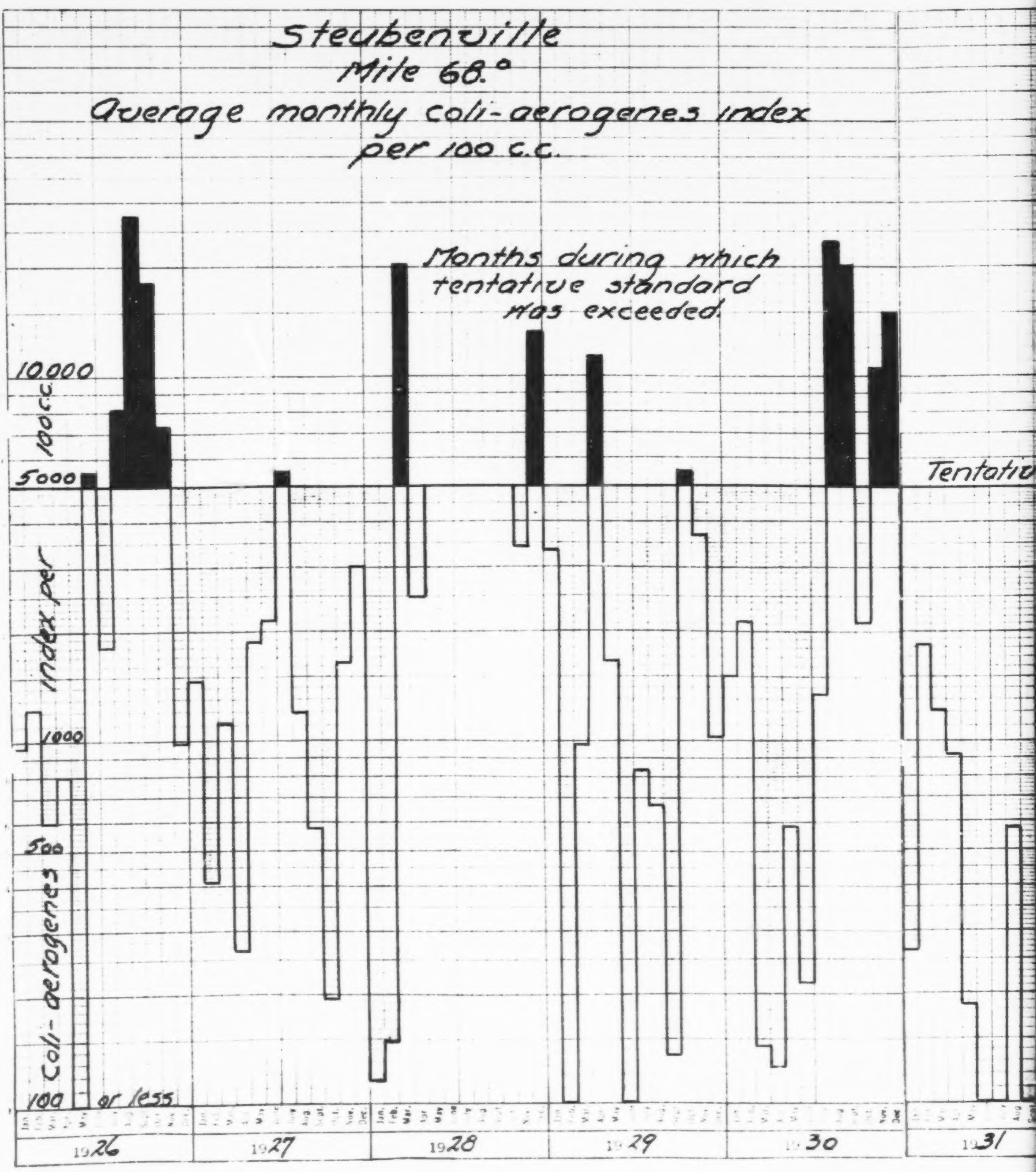
(Diagrams Nos. 13-23)



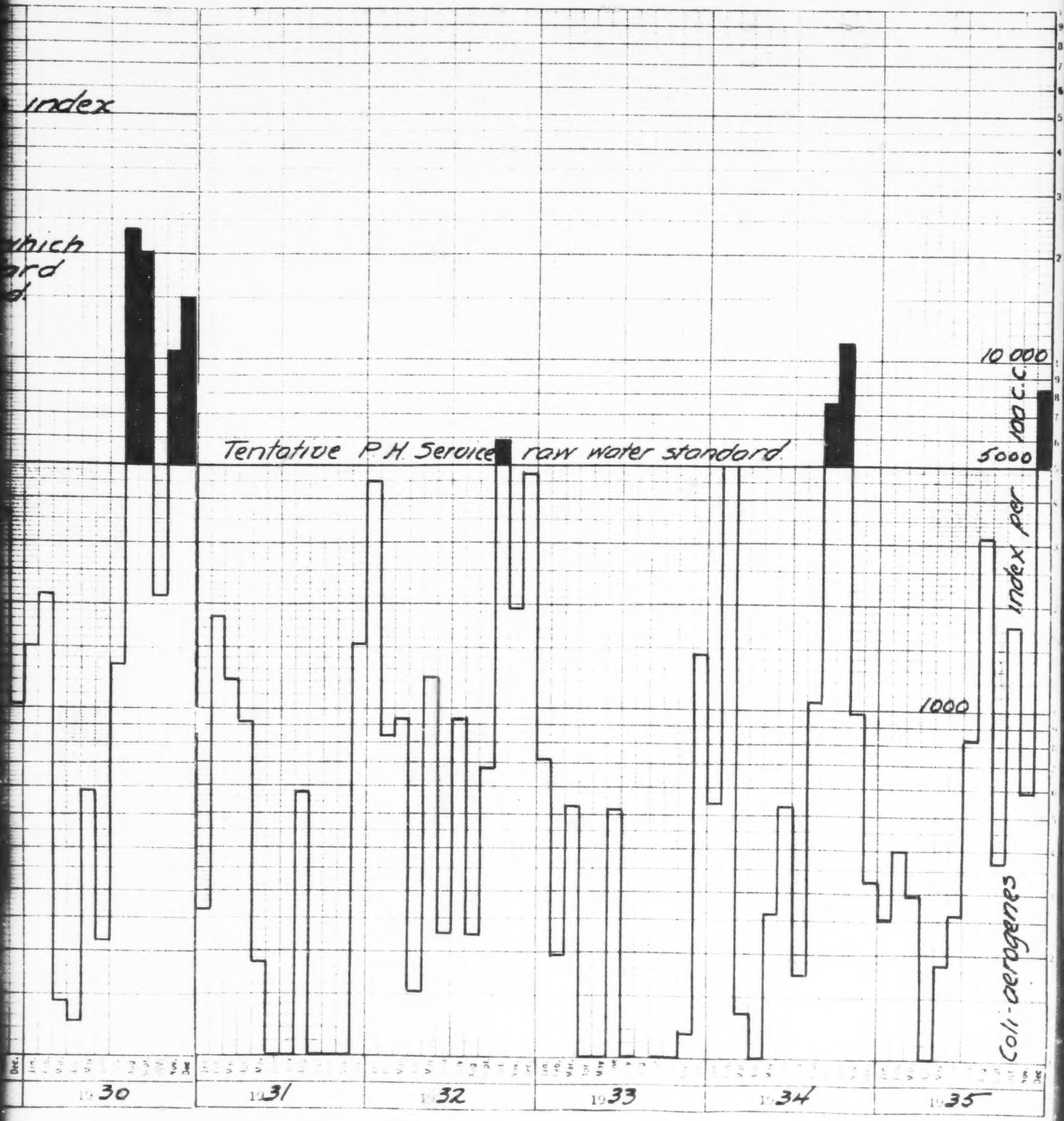
East Liverpool
Mile 43.5
average monthly
Coli-aerogenes Index
per 100 C.C.

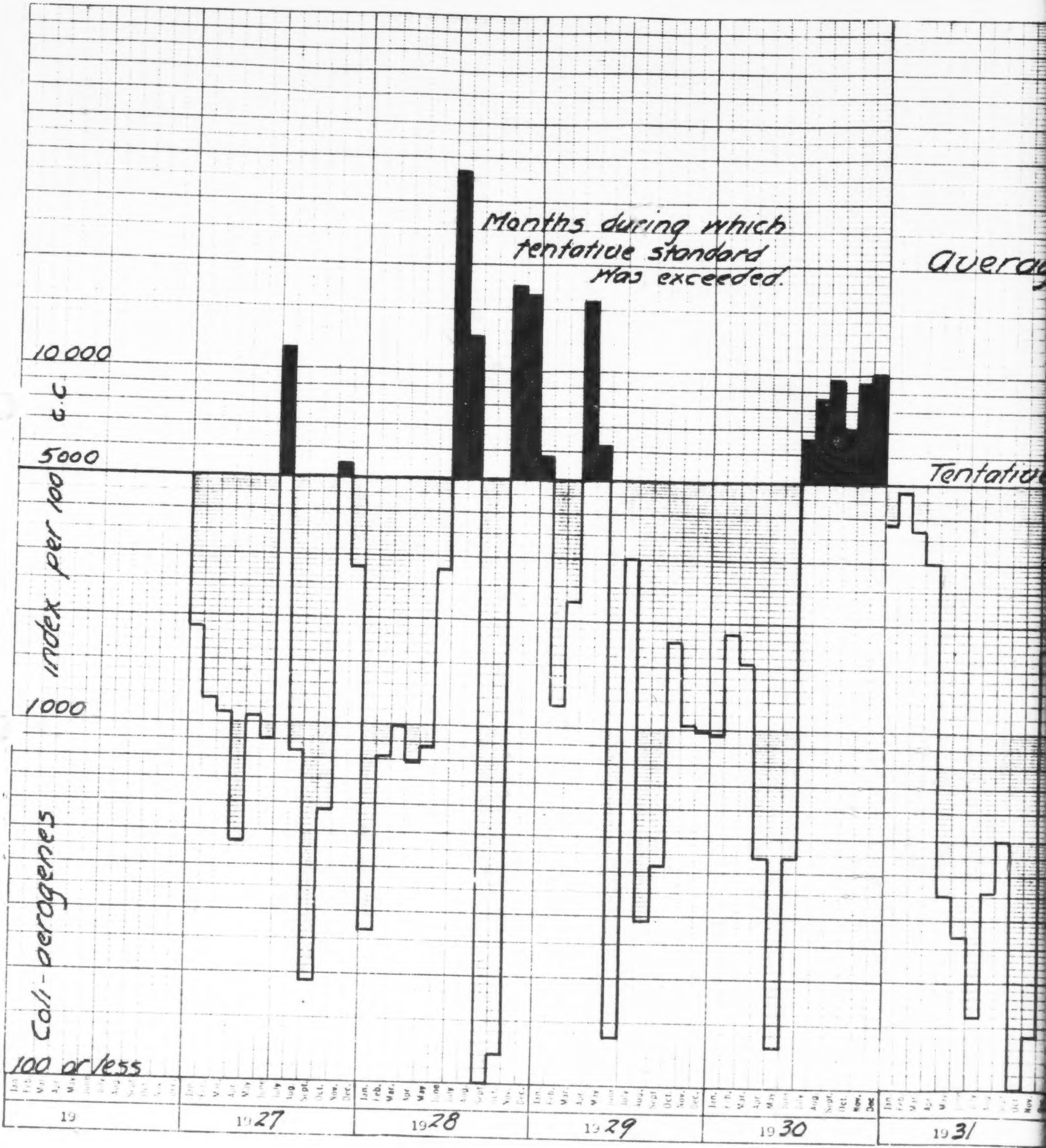
Months in which tentative Standard was exceeded.

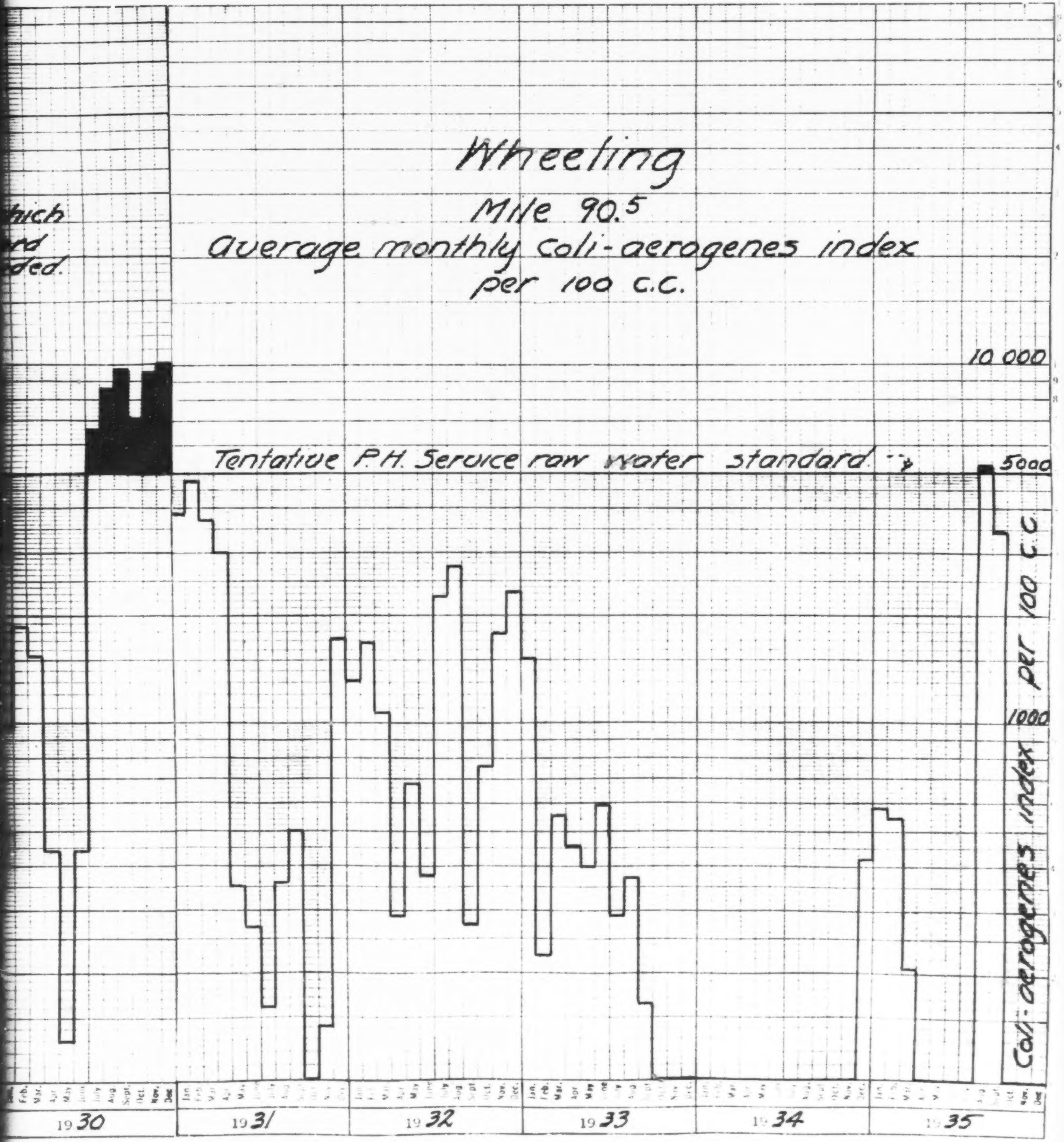
tative
eeded.
Tentative P.H. Service raw water standard
100 000
10000
1000
100
Coli-aerogenes index per 100 c.c.
1930
1931
1932
1933
1934
35
Jan.
Feb.
Mar.
Apr.
May
July
Aug.
Sept.
Oct.
Nov.
Dec.

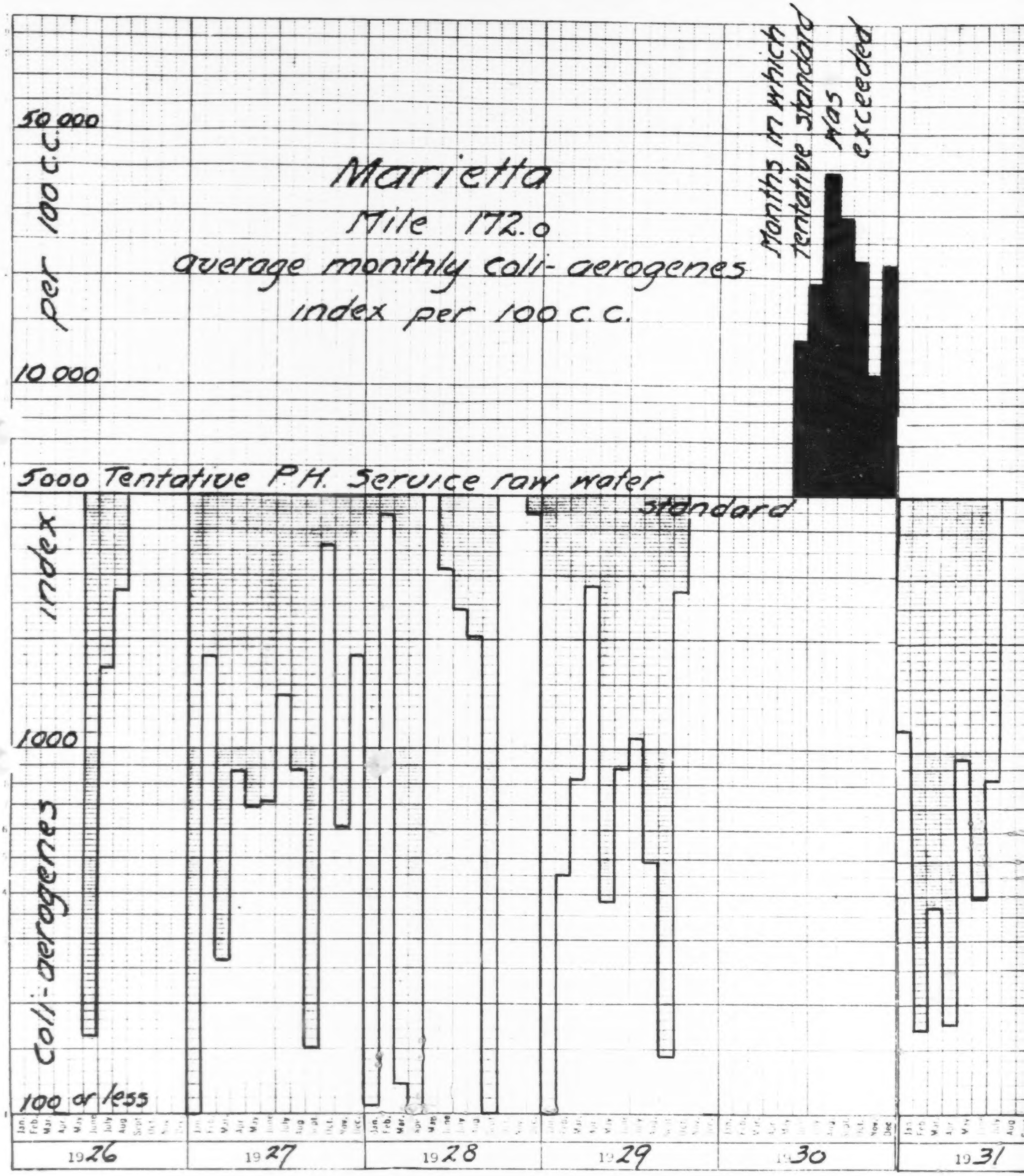


Steubenville
Mile 68.0
Average monthly coli-aerogenes index
per 100 c.c.

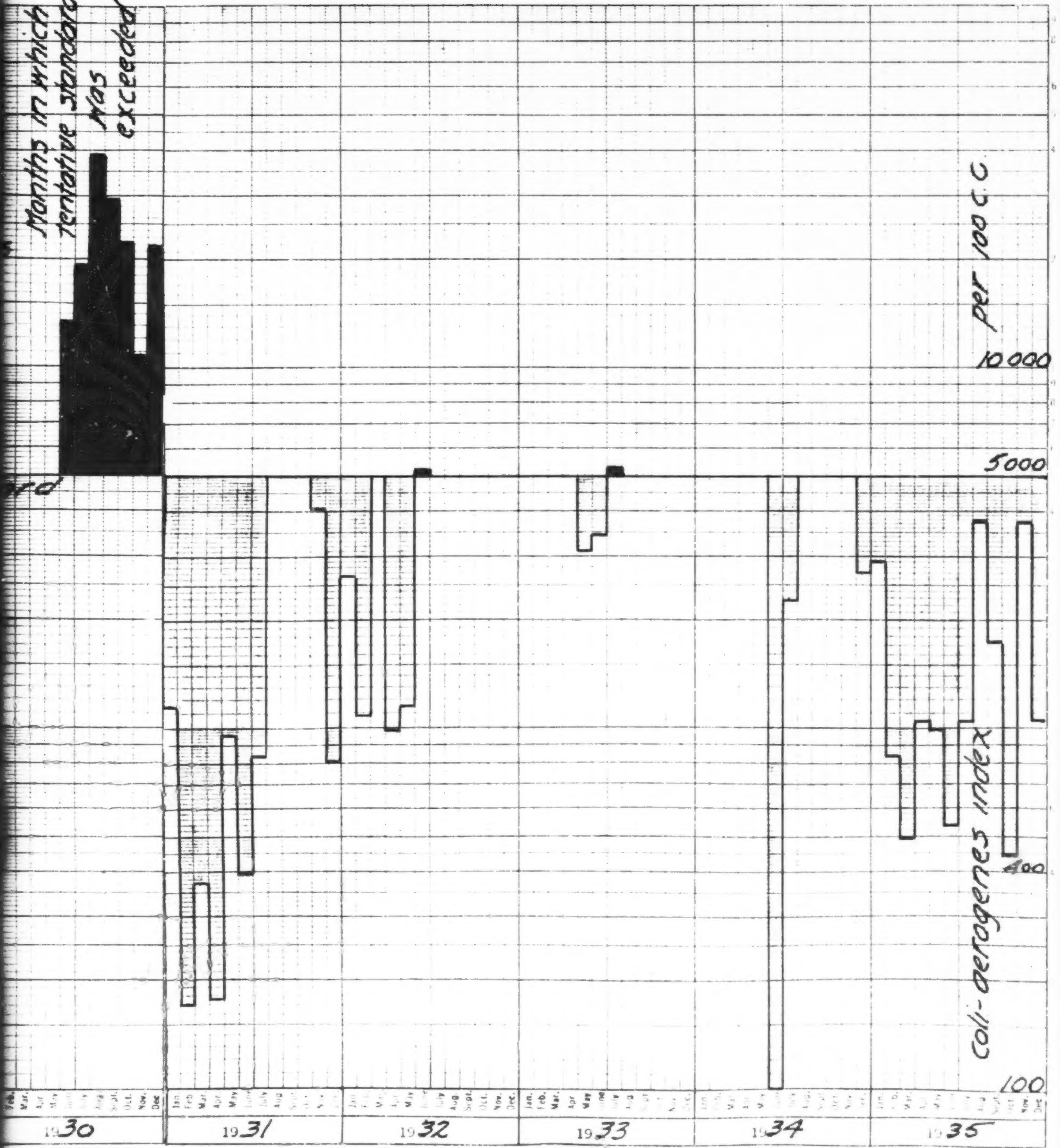

index
which
ard
d.
Tentative P.H. Service raw water standard
10 000
100 c.c.
5000
index per
1000
Coli-aerogenes
1930
1931
1932
1933
1934
1935

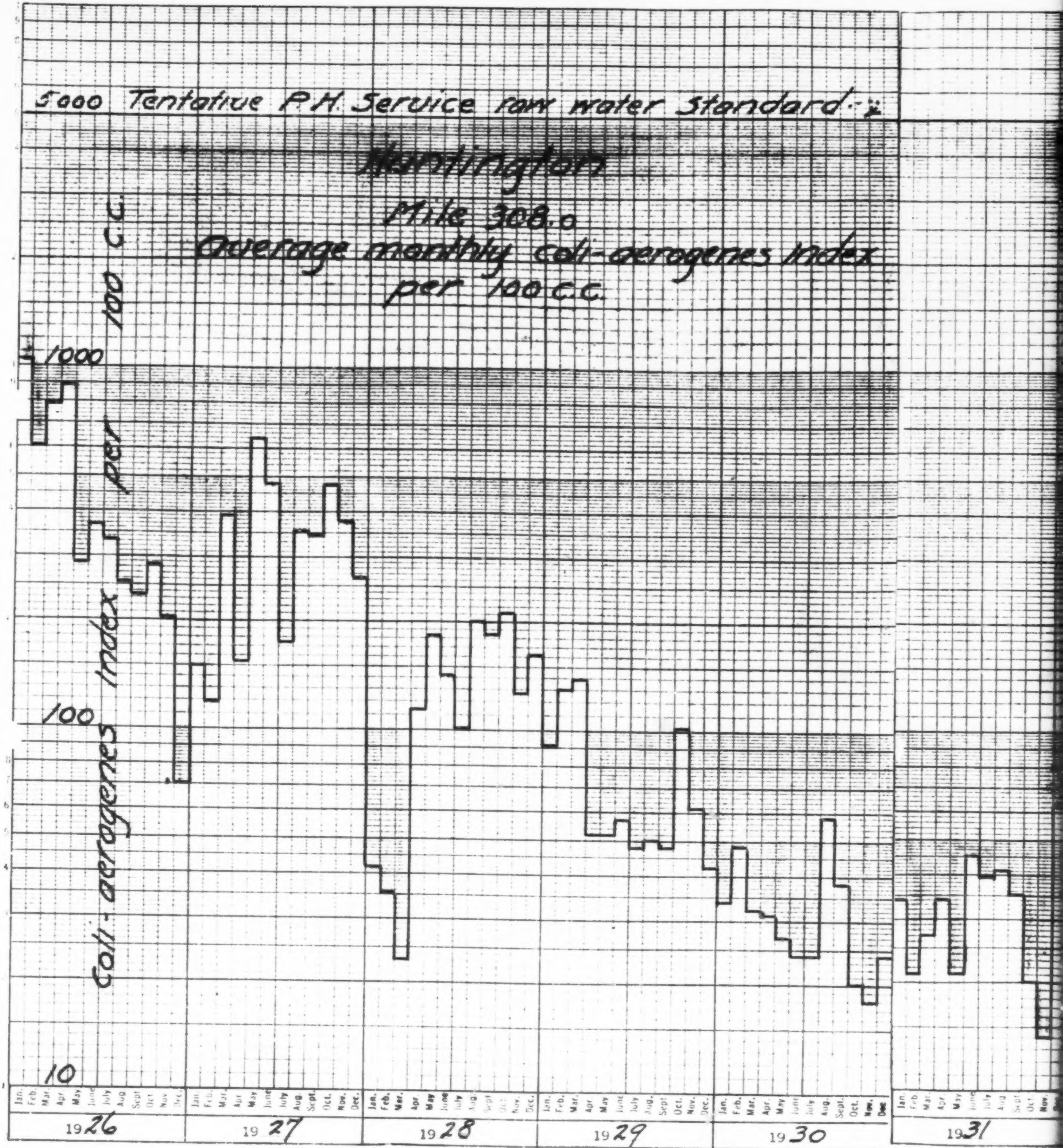

Months during which tentative standard was exceeded.
averag
10 000
5000
1000
100 or less
Coli-aerogenes index per 100 c.c
Tentative
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
19
1927
1928
1929
1930
1931

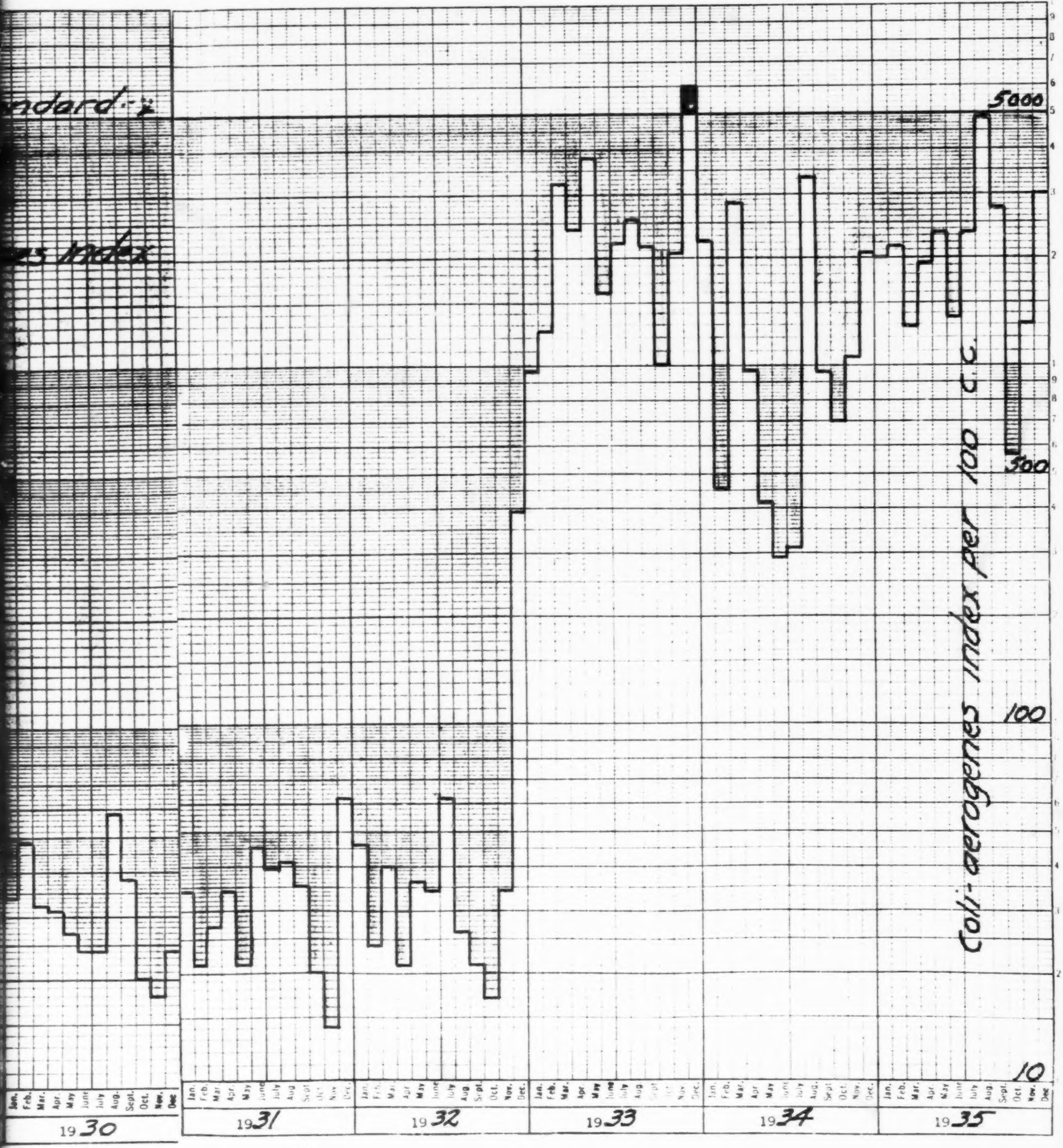

Wheeling
Mile 90.5
average monthly coli-aerogenes index per 100 c.c.
hich
rd
ded.
Tentative P.H. Service raw water standard
10 000
5000
1000
Coli-aerogenes index per 100 c.c.
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1930
1931
1932
1933
1934
1935



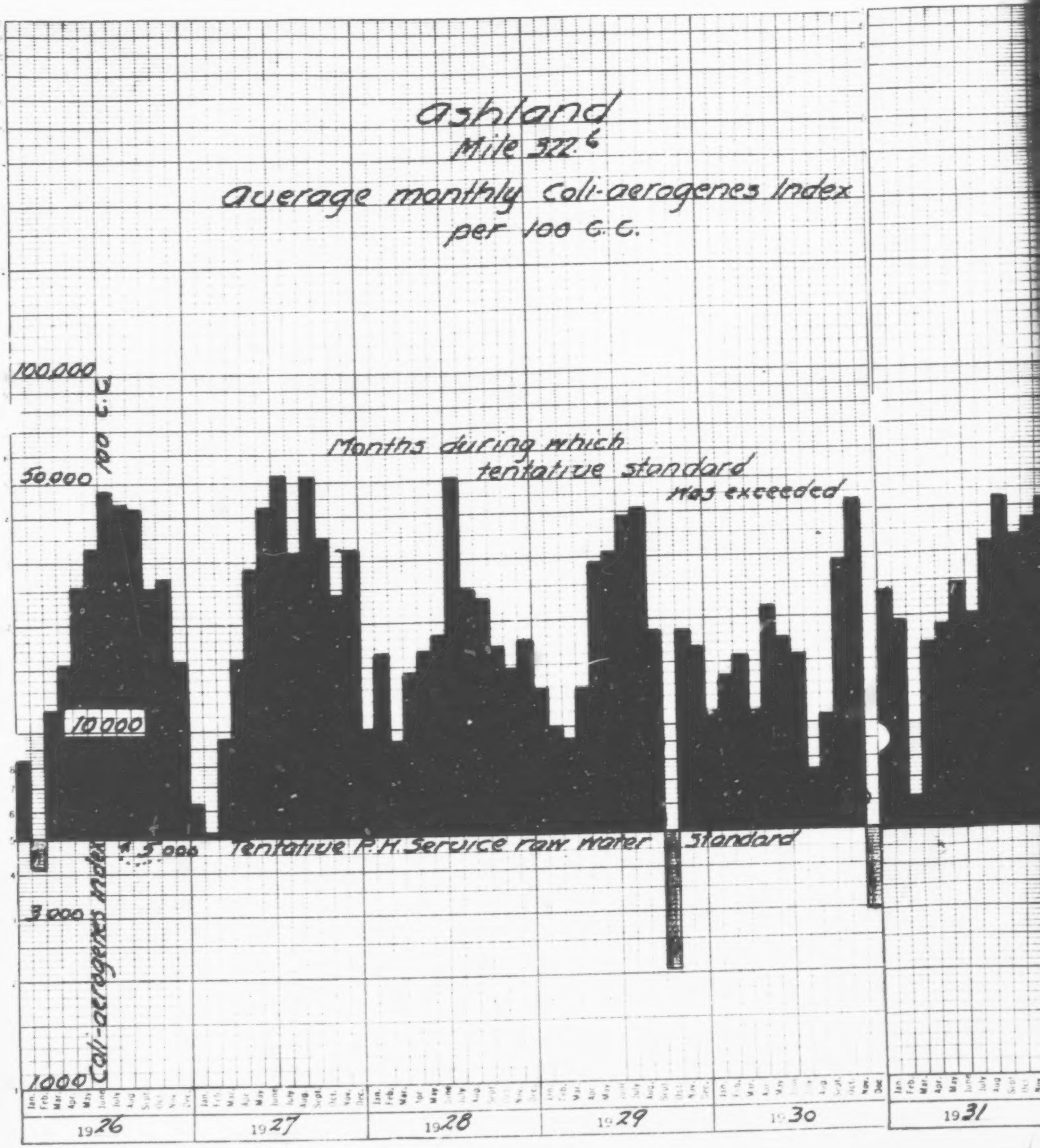
Marietta
Mile 172.0
average monthly coli-aerogenes index per 100 c.c.


Months in which tentative standard was exceeded
ard
per 100 c.c.
10 000
5000
400
100
Coli-aerogenes index
Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1930
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1931
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1932
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1933
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1934
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1935

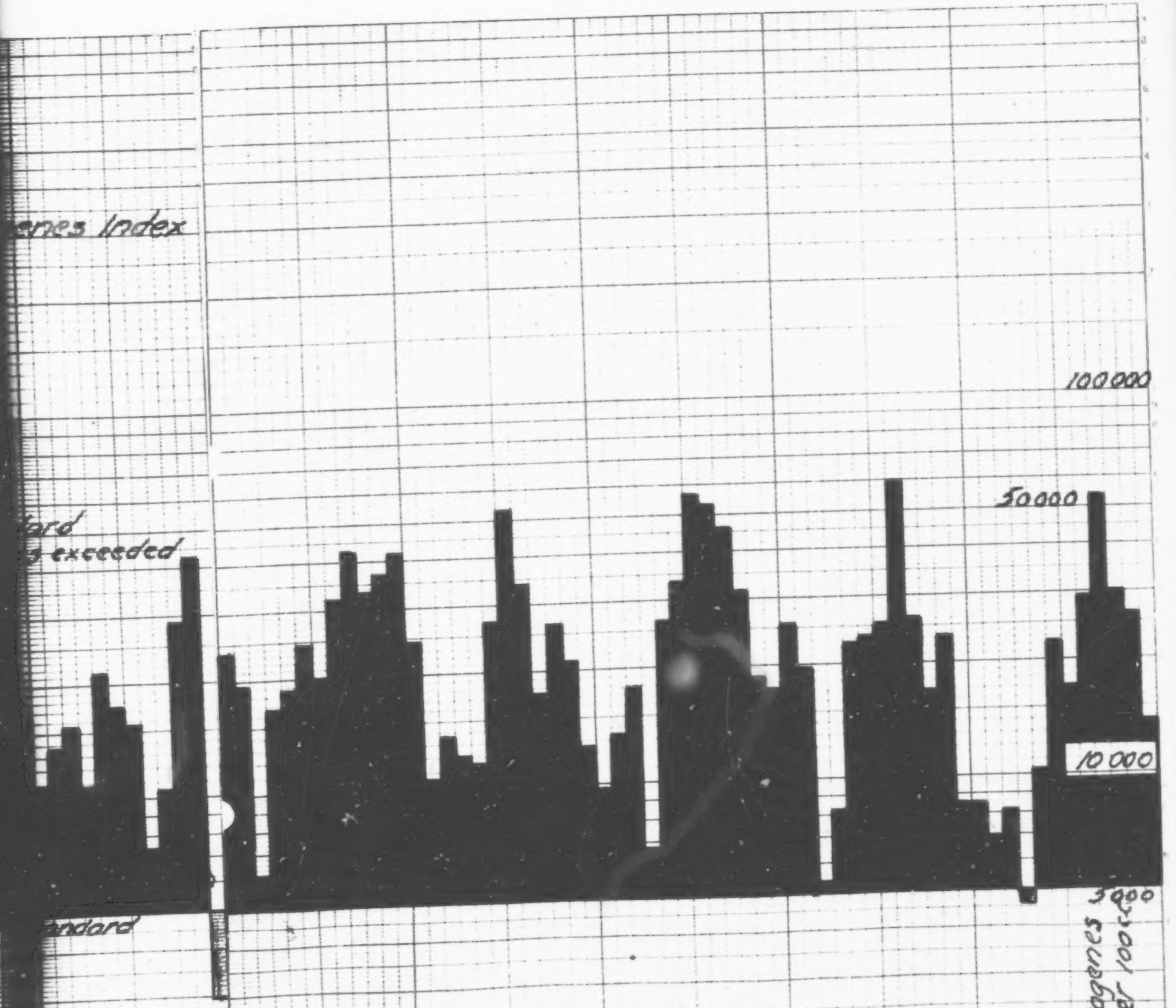

5000 Tentative P.H. Service raw water Standard
Huntington
Mile 308.0
Average monthly coli-aerogenes index
per 100 c.c.
Coli-aerogenes index per 100 c.c.
1000
100
10
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1926
1927
1928
1929
1930
1931


ndard
es Index
5000
500
100
10
Coli-aerogenes index per 100 c.c.
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1930
1931
1932
1933
1934
1935

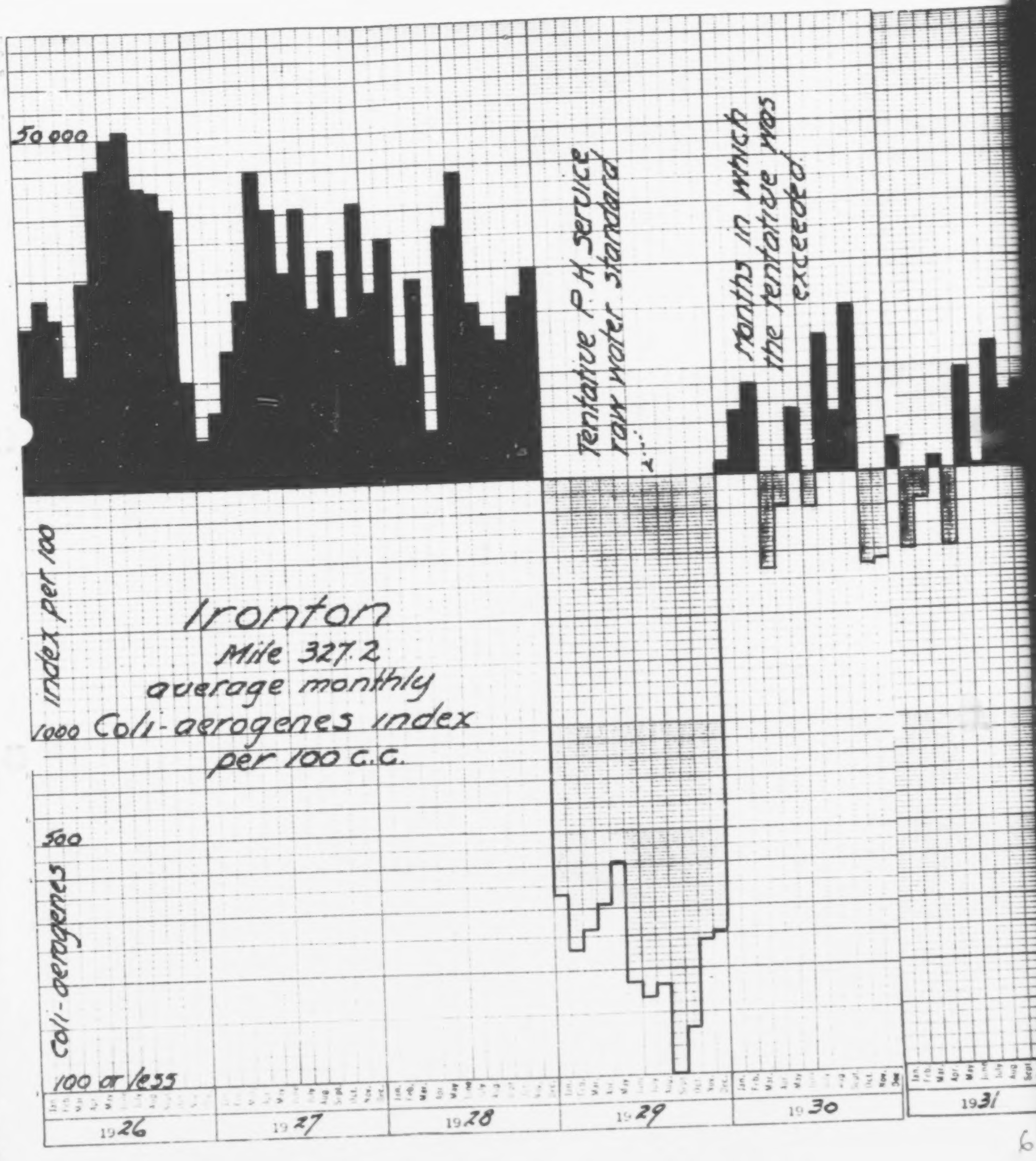
B

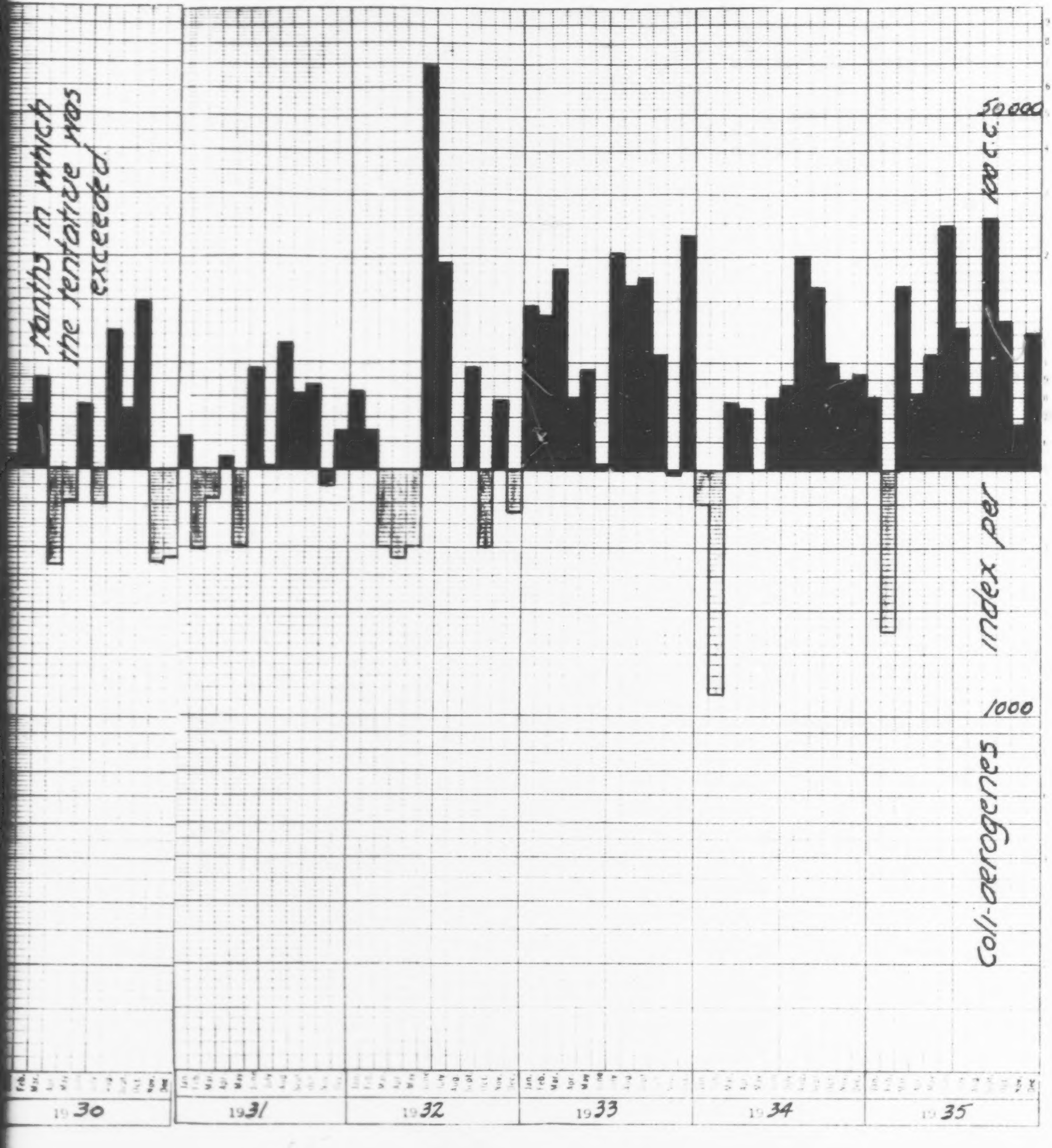


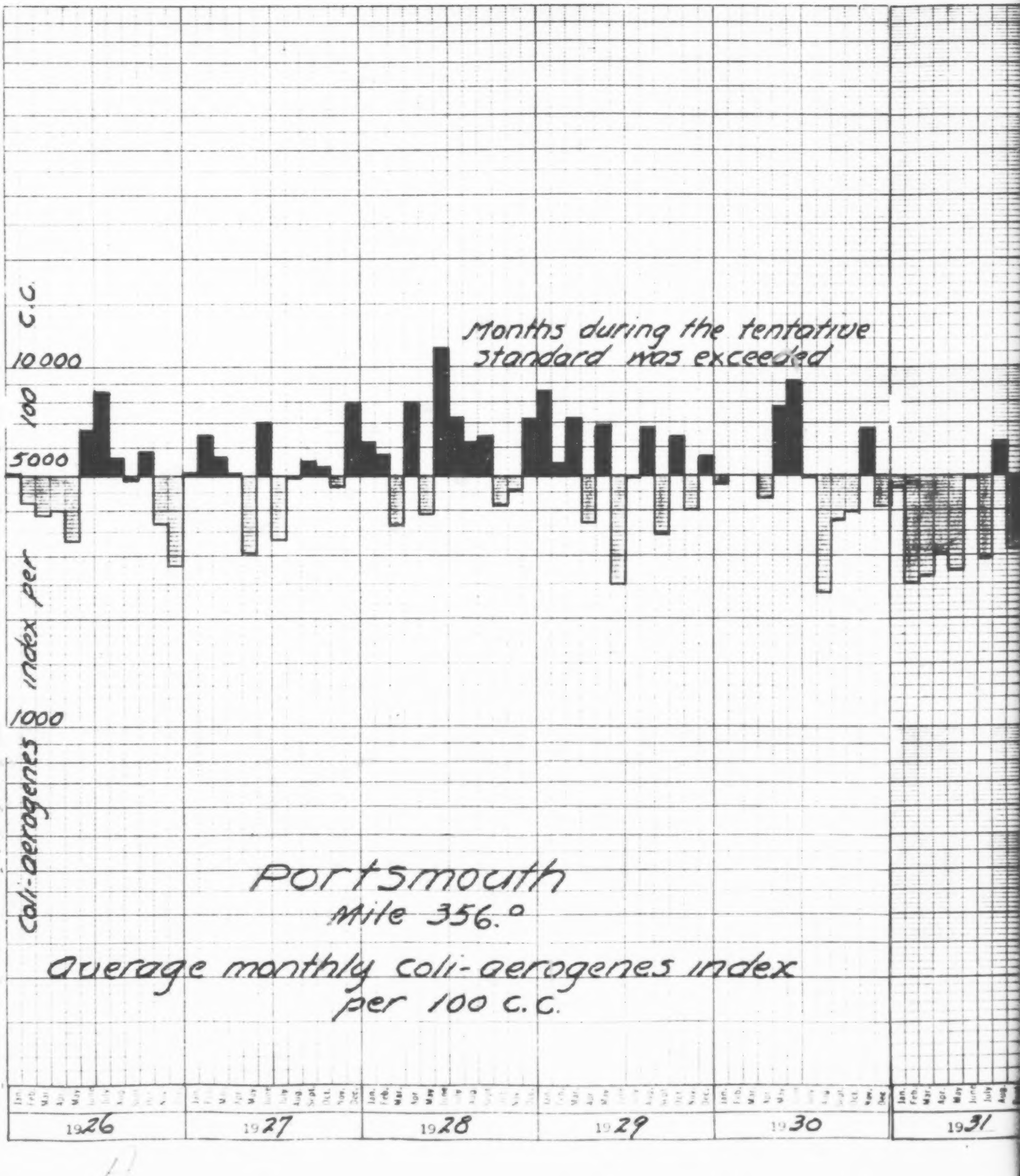
Ashland
Mile 322.6
Average monthly Coli-aerogenes Index
per 100 c.c.



enes Index
dard
s exceeded
andard
100,000
50000
10,000
5000
1000
Coli-aerogenes index per 100 cc
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1930
1931
1932
1933
1934
1935

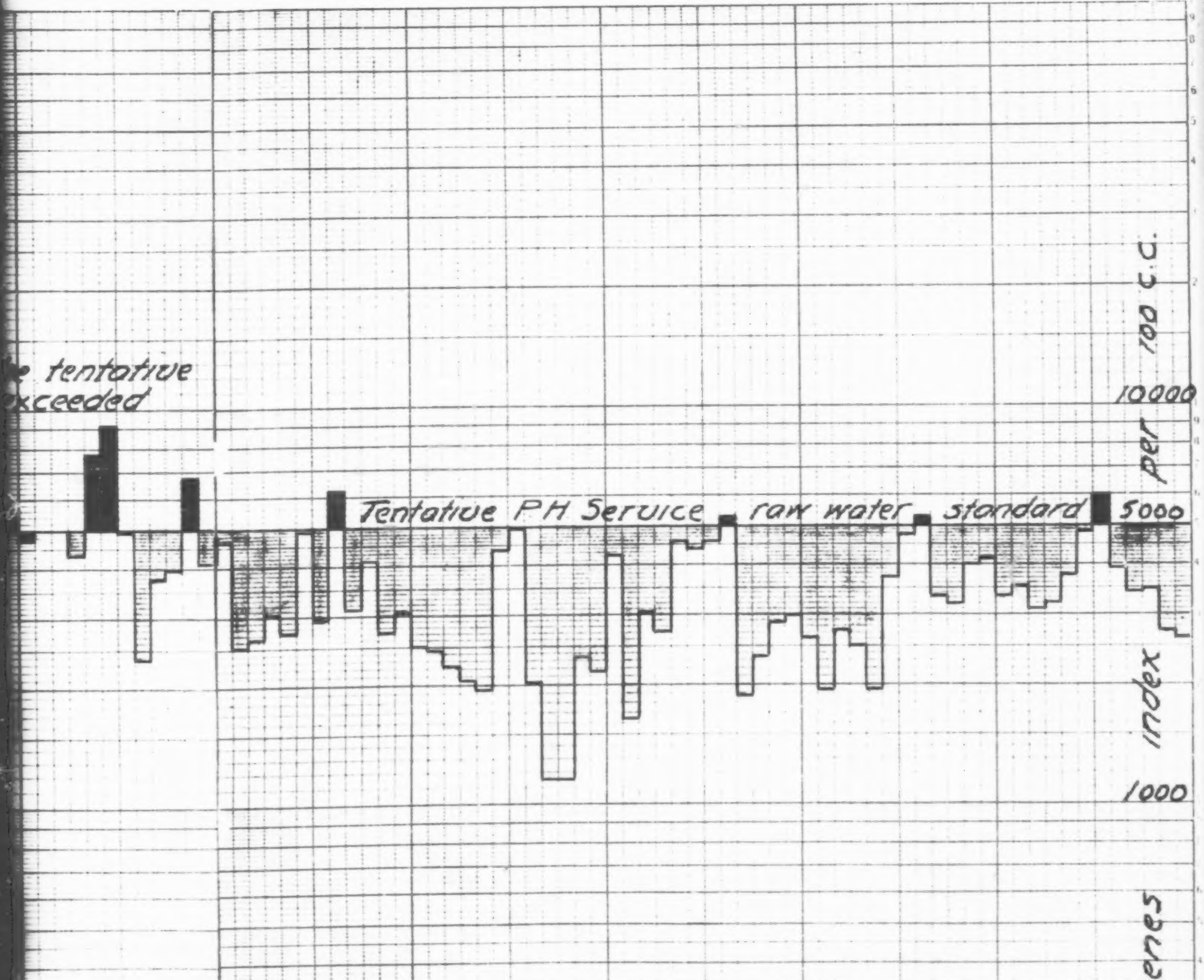

50 000
Tentative P.H. Service raw water standard
Months in which the tentative was exceeded
Ironton
Mile 327.2
average monthly
Coli-aerogenes index
per 100 c.c.
Coli-aerogenes index per 100
1000
500
100 or less
1926
1927
1928
1929
1930
1931

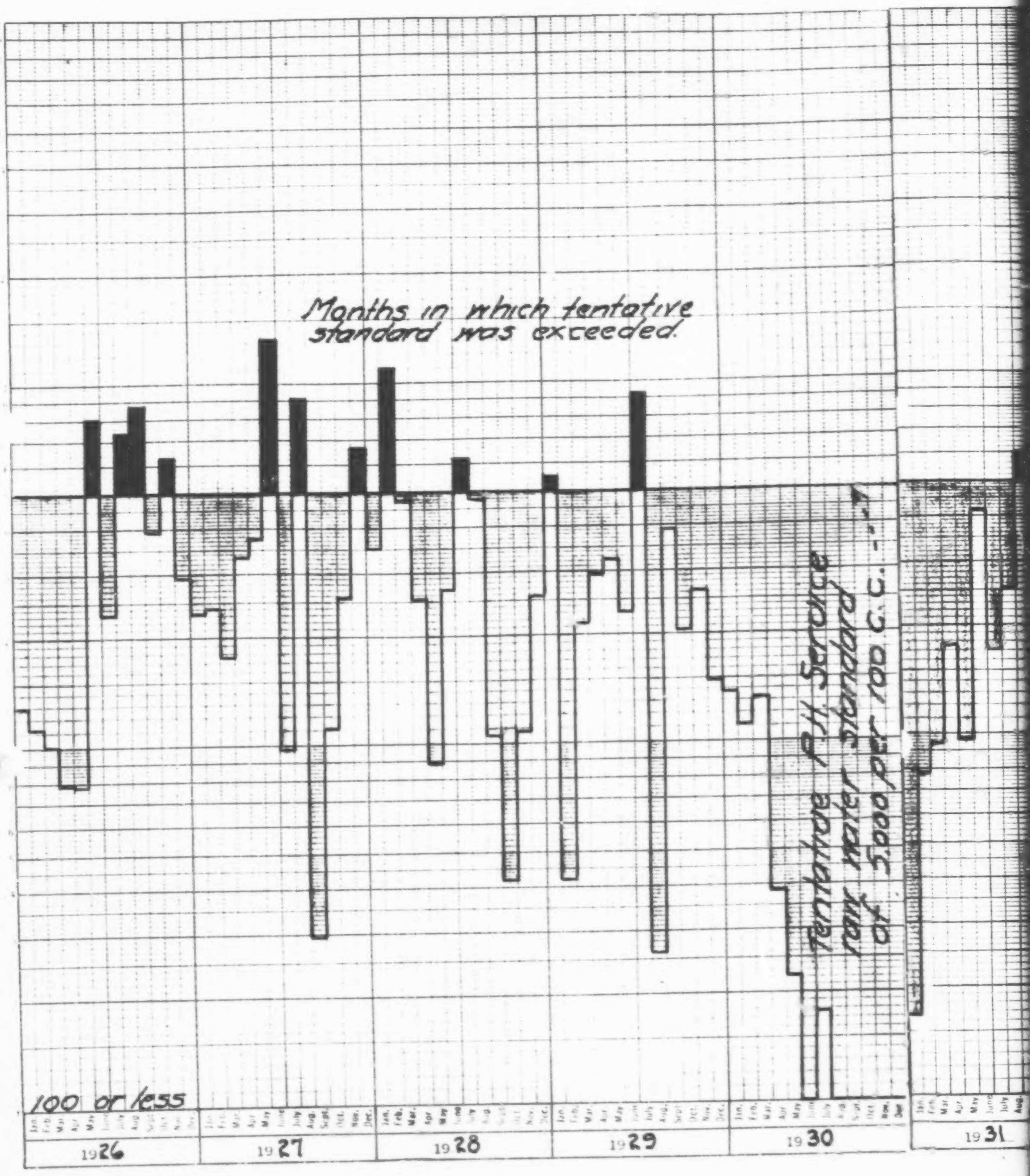

Months in which the tentative was exceeded
Coli-aerogenes index per 100 c.c.
50000
1000
1930
1931
1932
1933
1934
1935

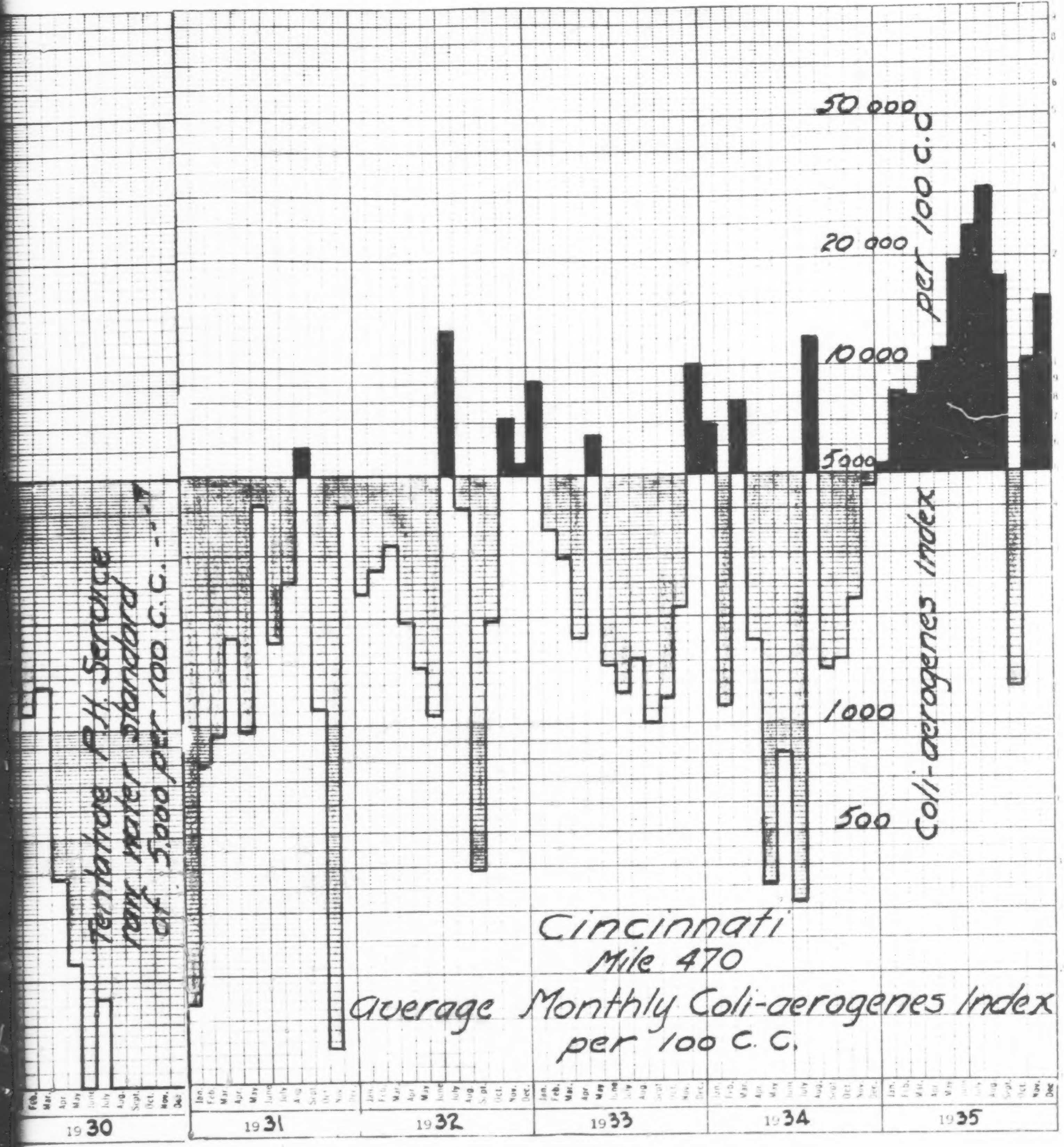


Portsmouth
Mile 356.0

Average monthly coli-aerogenes index per 100 C.C.


e tentative
xceeded
Tentative P.H. Service raw water standard
10000
5000
1000
Coli-aerogenes index per 100 c.c.
ndex
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1930
1931
1932
1933
1934
1935

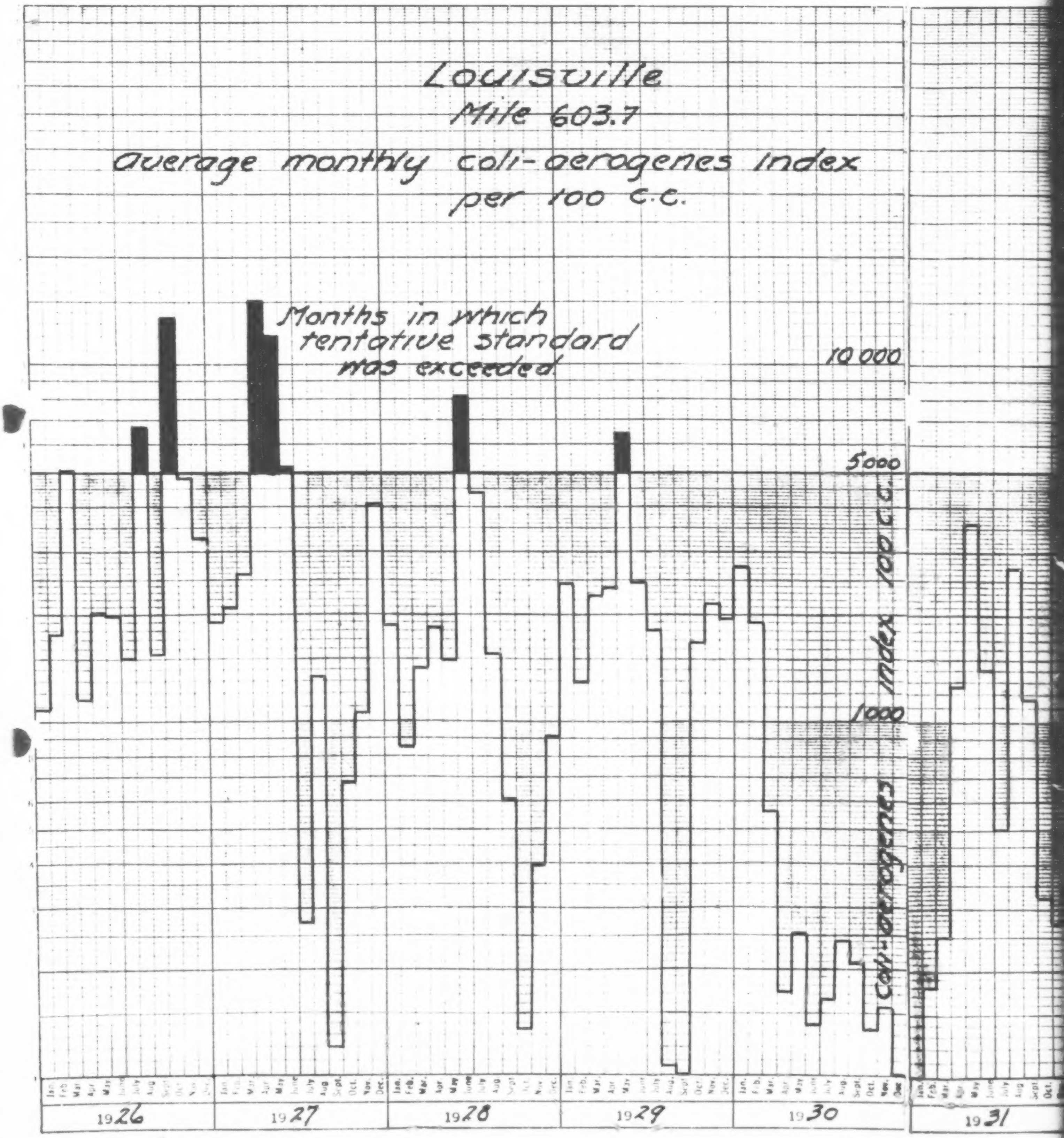
Months in which tentative standard was exceeded.
Tentative P.H. Service raw water standard of 5,000 per 100 C.C.
100 or less
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1926
1927
1928
1929
1930
1931

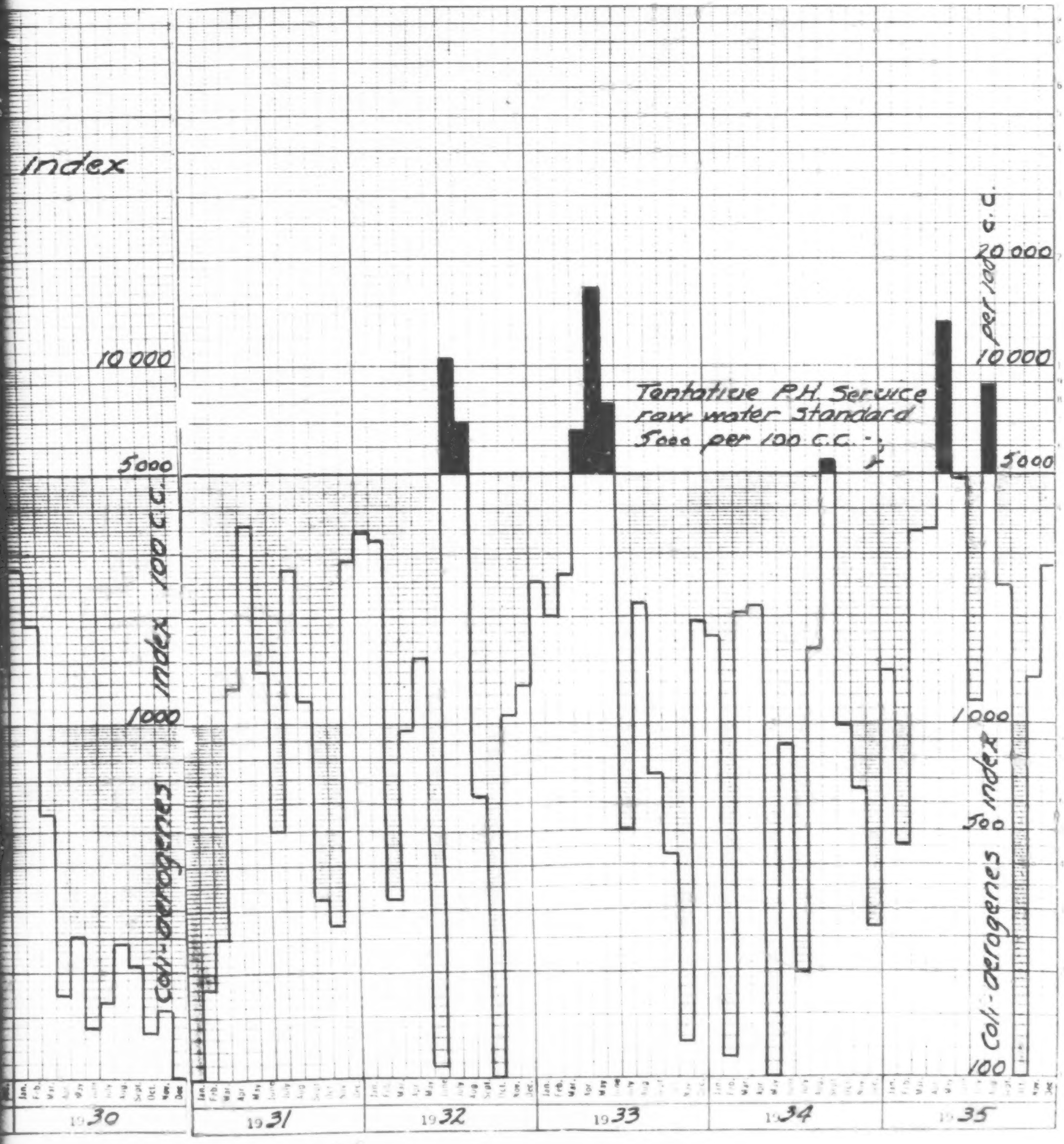


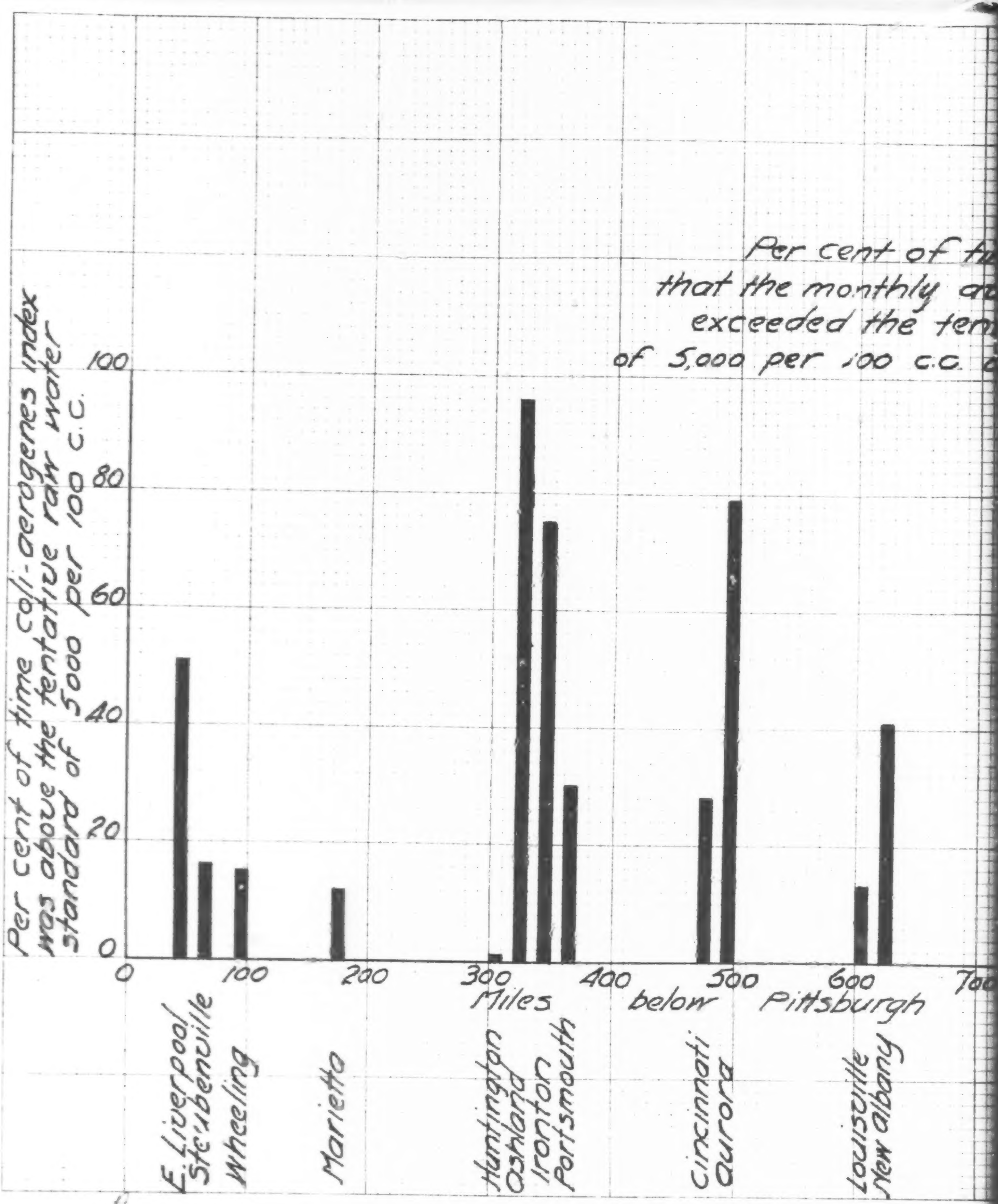
Cincinnati
Mile 470
Average Monthly Coli-aerogenes Index
per 100 C. C.

61

B


Louisville
Mile 603.7
average monthly coli-aerogenes index
per 100 c.c.
Months in which
tentative standard
was exceeded
10 000
5000
1000
Coli-aerogenes index 100 c.c.
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1926
1927
1928
1929
1930
1931


Index
10 000
5000
1000
Coli-aerogenes Index 100 C.C.
Tentative P.H. Service raw water Standard 5000 per 100 C.C.
20 000
10 000
5000
1000
500
100
Coli-aerogenes Index per 100 c.c.
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1930
1931
1932
1933
1934
1935


Per cent of ti
that the monthly a
exceeded the ten
of 5,000 per 100 c.c.
Per cent of time coli-aerogenes index was above the tentative raw water standard of 5000 per 100 c.c.
100
80
60
40
20
0
0
100
200
300
400
500
600
70
Miles below Pittsburgh
E. Liverpool
Steubenville
Wheeling
Marietta
Huntington
Ashland
Ironton
Portsmouth
Cincinnati
Aurora
Louisville
New albany

Per cent of time during 1926-1935
that the monthly average coli-aerogenes index
exceeded the tentative raw water index
of 5,000 per 100 c.c. at Ohio River treatment plants.

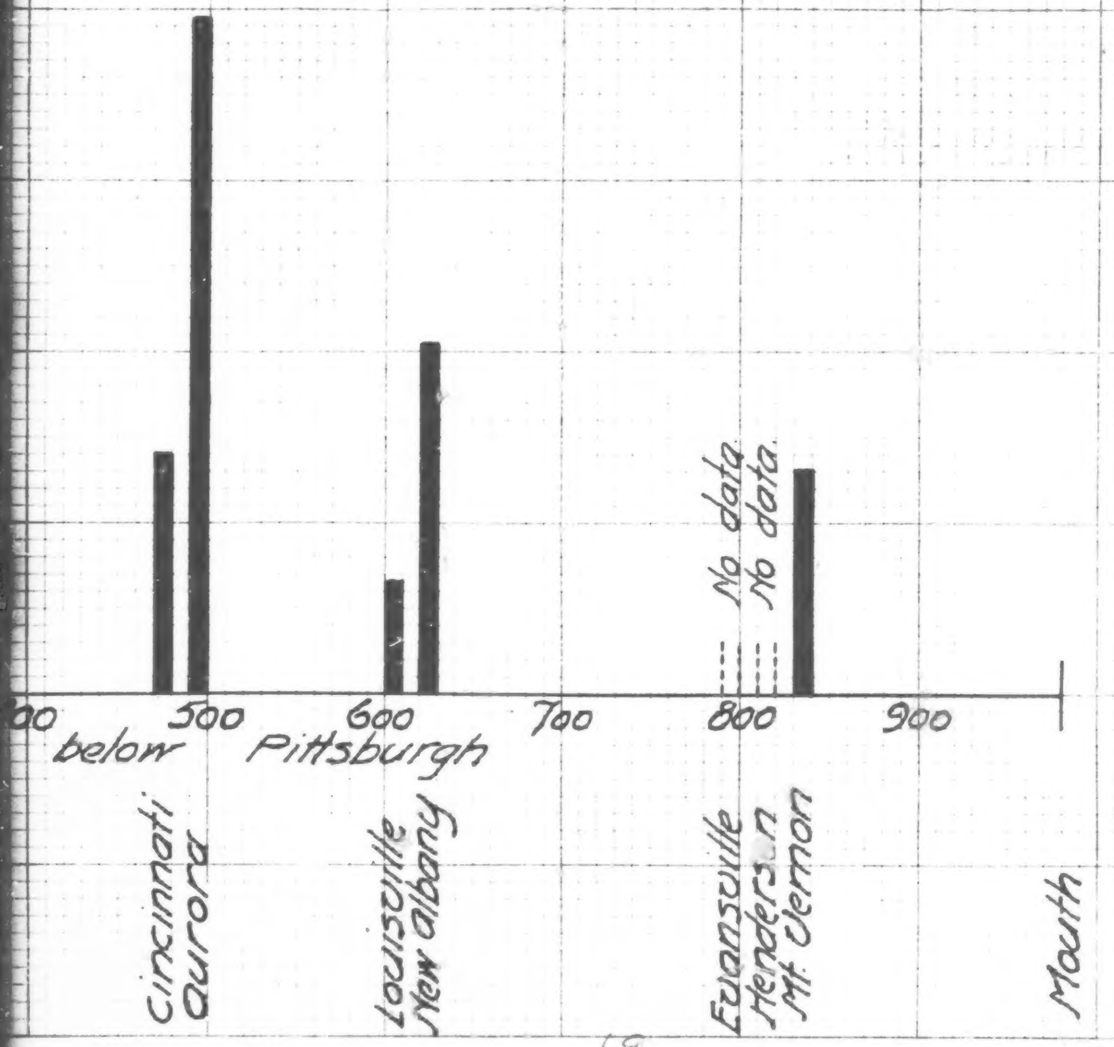


TABLE NO. 5. NUMBER OF MONTHS AND PERCENTAGE OF THE TIME, DURING THE TEN YEAR PERIOD 1926-1935, INCLUSIVE WHEN THE MONTHLY AVERAGE COLI-AEROGENES INDEX OF UNTREATED OHIO RIVER WATER AT FILTRATION PLANTS ALONG THE RIVER EXCEEDED THE TENTATIVE RAW WATER STANDARD OF 5,000 PER 100 CUBIC CENTIMETERS AND THE PERCENTAGE OF THE TIME WHEN THE MONTHLY AVERAGE INDEX WAS BETWEEN DESIGNATED LIMITS.

Community	Miles below Pittsburgh	Per cent of time raw water standard was exceeded. (X)	Per cent of time that average monthly index was between:								Daily maximum coli-aerogenes index per 100 c. c.
			5,000 and 15,000	15,000 and 25,000	25,000 and 35,000	35,000 and 45,000	45,000 and 55,000	55,000 and 65,000	65,000 and 75,000	over 100,000	
E.Liverpool[a]	43.5	50	29	9	4	4	1	0	2	1	1,000,000
Steubenville[b]	68.0	16	11	4	1						1,000,000
Wheeling[c]	90.5	15	11	3	0	1					100,000
Marietta[d]	172.0	12	5	4	1	1					- - -
Huntington	308.3	1	1								10,000
Ashland	322.6	97	30	29	20	9	7	2			100,000[f]
Ironton	327.2	75	42	21	5	4	2	0	1		1,000,000
Portsmouth	356.0	30	30								100,000
Cincinnati	470.2	27	23	3	1						100,000
Aurora[e]	496.7	Index exceeds 6,000 about 79% of the time; 20,000 about 42%									100,000[f]
Louisville	603.7	13	12	1							100,000
New Albany[e]	608.5	Index exceeds 6,000 about 41% of the time									100,000[f]
Evansville	792.3	No data available									No data
Henderson	803.9	No data available									No data
Mt. Vernon[e]	829.1	Index exceeds 6,000 about 26% of the time									40,000

(X) Tentative raw water standard of 5,000 coli-aerogenes organisms per 100 cubic centimeters

[a] Twelve months missing during 1933 and 1934.

[b] Eight months missing during 1928-1933-1934.

[c] Nine year record only, 1927-1935, inclusive.

[d] Seventy-five (75) months record only.

[e] Data supplied by Indiana Department of Commerce and Industry.

[f] Insuffivient dilution of samples tested, maximum may be higher

The summary of monthly averages of coli-aerogenes indices indicates a zone of heavy pollution in the Pittsburgh-East Liverpool section of the stream; a decrease in pollution between East Liverpool and Huntington; a zone of maximum pollution in the Ashland-Ironton area; and then in general a decrease in the amount of pollution in the lower section of the river, with temporary but marked increases at points immediately below zones of major pollution such as Cincinnati and Louisville.

The effects of natural stream purification are particularly noticeable during the long period of pool stage in 1929-30 and again in 1933-34, at Cincinnati and Louisville indicative of conditions in the lower Ohio River, and at Ironton, Wheeling, Marietta and Steubenville in 1929-30 on the upper river. In most every instance a noticeable increase in bacterial pollution occurred late in 1930 or early in 1931 as river stages increased to produce scour following the long period of pool conditions.

In some instances pool stages, combined with tributary inflow, cause reversals of flow in the main river which result in pollution from downstream local sources reaching the water supply intake. Such was the case at Charleston, W. Va., in 1930, when intestinal disturbances affected some

10,000 of the city's 60,000 inhabitants due to reversal of flow in the Elk River. Pollution of the Cincinnati raw water supply has been observed at times of excessive run-off from the highly polluted Little Miami River due to local storms on that watershed which caused storm waters to flow both downstream and upstream in the Ohio River, carrying sewage-polluted water to the water works intake.

Monthly averages also indicate that in general the tentative raw water standard of 5,000 coli-aerogenes organisms per 100 cc. of water is more liable to be exceeded in the months of October to April, inclusive, when stream discharge is higher, than in the period May to September, inclusive, when stream flows are lower and the river at pool stage.

The daily coli-aerogenes index is of course greatly in excess of the monthly averages and the variation in the degree of pollution much greater, depending upon the effects of rainfall and run-off on the main stream, the influence of tributary inflow, and the manipulation of the navigation dams. The maximum daily coli-aerogenes index at the various water filtration plants is indicated on Table No. 5.

Bacterial analyses of the raw Ohio River water at the East Liverpool filtration plant indicate that the tentative raw water standard of 5,000 per 100 cc. was exceeded in 54 of the 108 months for which data are available, that is, 50 per cent of the time. For about 21 per cent of the time the average monthly index was over 15,000 per 100 cc. The maximum monthly average of 118,000 per 100 cc. in September, 1926, indicates that during one or more days the pollution this month must have been such as to place a tremendous bacterial load on the filter plant.

Below East Liverpool the intensity of pollution appears to decrease somewhat, the tentative raw water standard being exceeded at Steubenville and Wheeling about 16 per cent of the time, and at Huntington less than 1 per cent of the time. At Steubenville, Wheeling and Marietta the maximum monthly averages reach between 35,000 and 45,000 per 100 cc.

The highest consistent bacterial pollution in the Ohio River is indicated in the Ashland-Ironton area of the stream in a distance of approximately 19 miles. Undoubtedly the sewage from nearby upstream communities is a factor at Ashland and Ironton; the sewage from Huntington, population 75,570, entering the river 14.3 miles above Ashland, and the sewage from Ashland, population 29,070, entering 4.6 miles above Ironton. The 116 months when the tentative raw water standard of 5,000 per 100 cc. was exceeded at Ashland represents approximately 97 per cent of the time, while at

Ironton the standard was exceeded about 75 per cent of the time. The maximum intensity of pollution in this section of the river is indicated by the maximum monthly averages, which reached between 55,000 and 65,000 per 100 cc. twice at Ashland and between 65,000 and 75,000 once at Ironton.

At Portsmouth, 29 miles below Ironton, the intensity of pollution appears to decrease, the tentative standard being exceeded about 30 per cent of the time and the maximum reaching between 10,000 and 20,000 per 100 cc. A further decrease in pollution is indicated at Cincinnati and Louisville, the tentative standard at the former being exceeded about 27 per cent of the time, and at the latter intake about 13 per cent of the time.

In addition to Cincinnati and Louisville, two other communities, at which bacteriological data are available but limited in amount, obtain their water supplies from the Ohio River in the Cincinnati-Louisville section: Aurora, Indiana, located at Mile 497, about 20 miles below the lower Cincinnati sewer outlets, and New Albany, Indiana, located at about Mile 608, opposite some and below other of the Louisville sewer outlets.

According to information made available by the Indiana Department of Commerce and Industry, Aurora has a raw water coli-aerogenes index that reaches 1,000,000 per 100 cubic centimeters at times, exceeds 5,000 per 100 cc. nearly 80 per cent of the time, and 20,000 per 100 cc. about 42 per cent of the time. According to the same authority, the maximum daily coli-aerogenes index at New Albany is at least 100,000 per 100 cc. and possibly higher, 5,000 per 100 cc. being exceeded about 41 per cent of the time.

It is interesting to note that the City of Covington, Kentucky, taking water from approximately the same location as the City of Cincinnati, has depended wholly in the past upon a long period of storage followed by chlorination for the treatment of its water supply.

At New Albany, within the zone of pollution from Louisville, river water is said to be pumped to the storage basins during the night in an attempt to obtain the least heavily polluted river water, the water then being settled for a long period of time and often prechlorinated, in order to reduce the excess bacterial load to the point where the water can be handled in the usual type of filtration plant.

At Mount Vernon, Indiana, located at Mile 829, the coli-aerogenes index of the raw water exceeds 5,000 per 100 cc. about 26 per cent of the time and has reached a daily maximum of 40,000.

Daily Fluctuations in Coli-Aerogenes Index.

At East Liverpool, Steubenville and Ironton, the daily coli-aerogenes index has reached 1,000,000 per 100 cc. At Ashland, Aurora and New Albany the index on certain days has probably reached 1,000,000 per 100 cc. At Wheeling, Portsmouth, Cincinnati and Louisville, the maximum daily index at times reaches 100,000 per 100 cc. If conditions in the lower section of the Ohio River are indicated by the raw water index at Mount Vernon, then there is a still further decrease in the intensity of pollution, the maximum daily coli-aerogenes index reaching 40,000 per 100 cc.

Daily indices indicate frequent increases from 100 to 10,000 per 100 cc. and from 1,000 to 100,000 per 100 cc. on successive days.

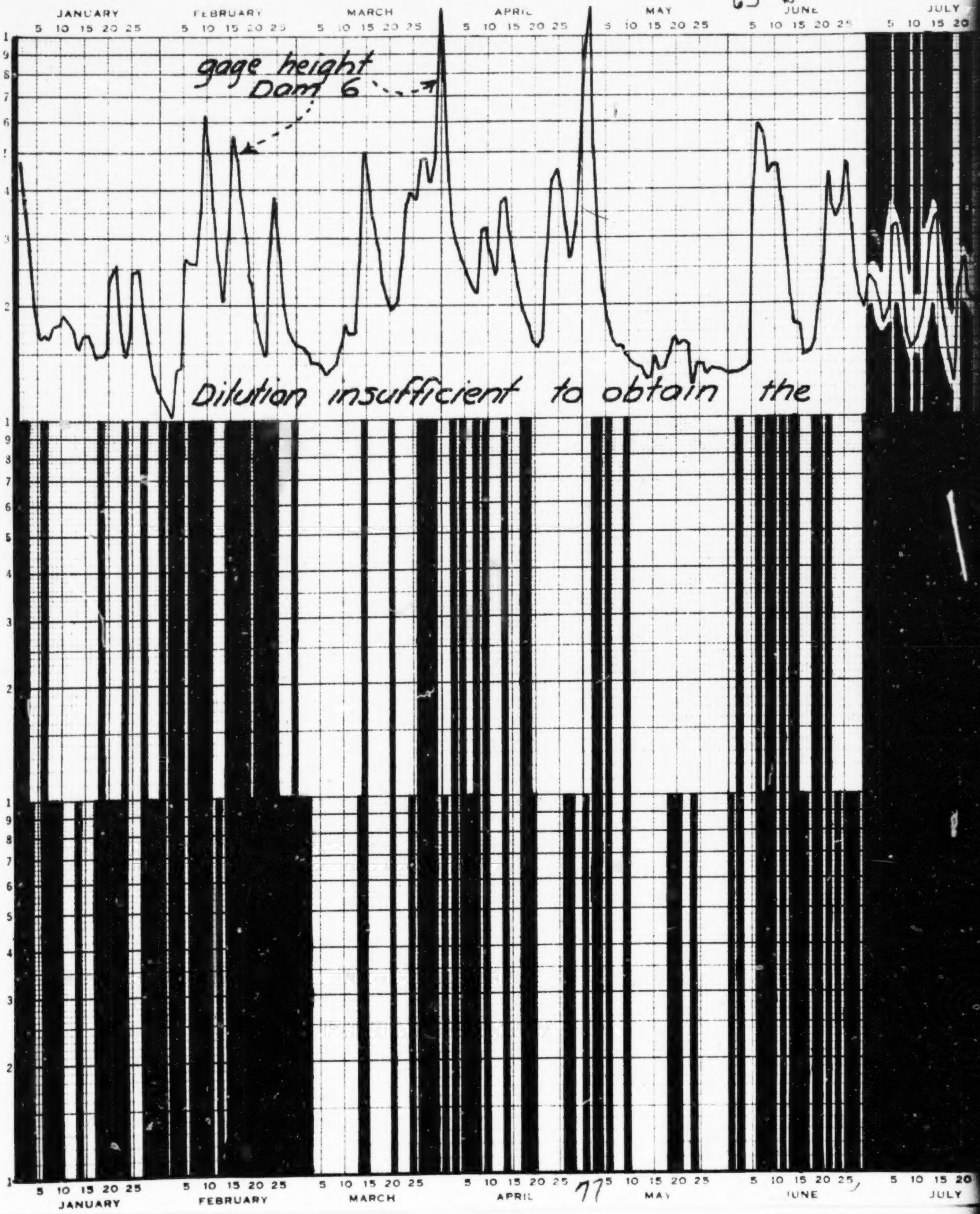
A comparison between the daily coli-aerogenes index and changes in gage height at various points along the river indicate a rather close relationship between the two.

A comparison between the daily coli-aerogenes index of the untreated Ohio River water at the East Liverpool water works intake during the year 1928 and the daily gage height of the river at Lock No. 6 located about 14 miles above the intake, is shown in Diagram No. 24. The rapid daily changes in the bacteriological quality of the river water, in the upper section of the Ohio River, and the effect of changes in river stage on the quality of the water, are indicated.

(Diagram No. 24)

1928 : East Liverpool : Comparison between daily

65-B



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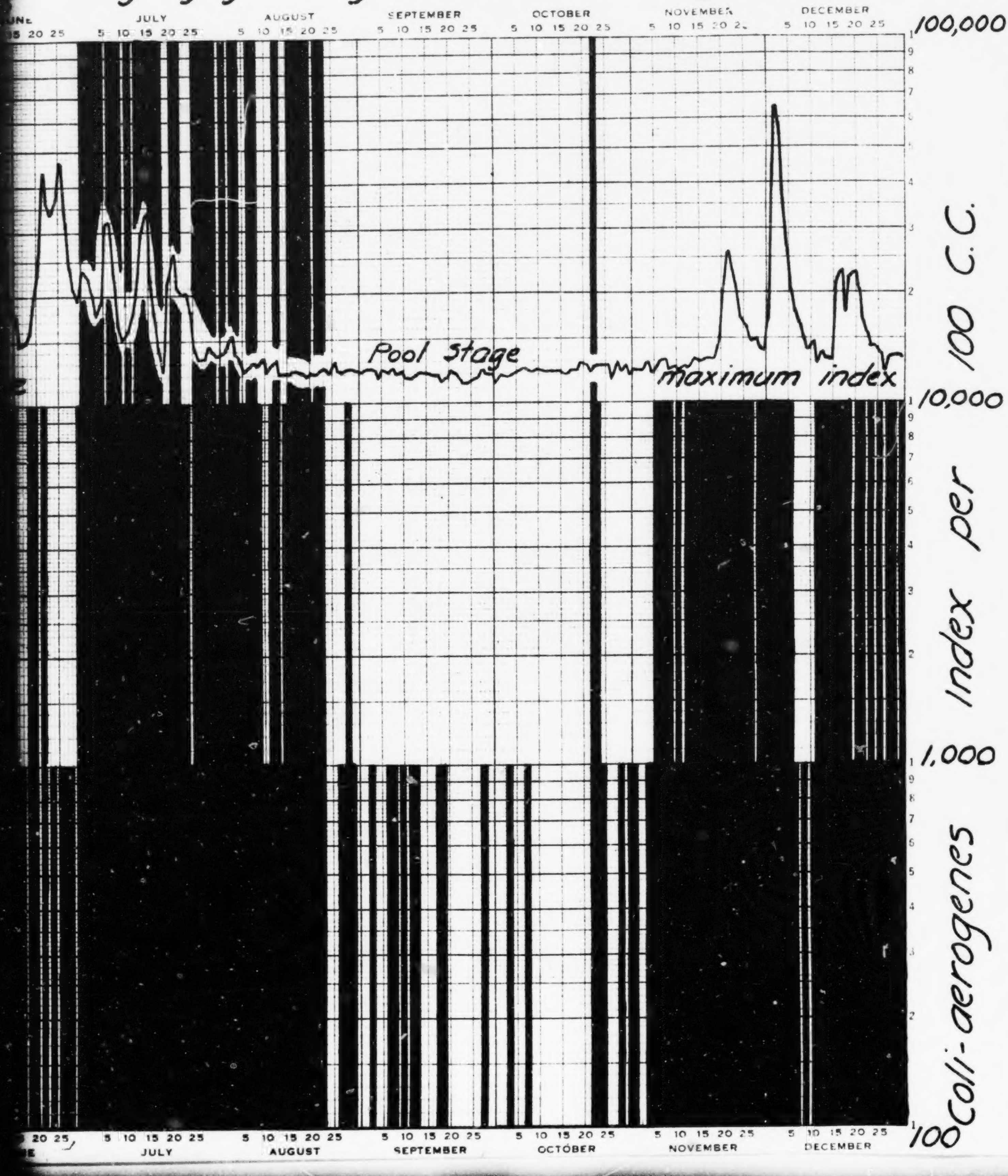
n daily gage height and Coli-aerogenes index



During the months of September and October, when the river was at pool stage, the daily index in general was consistently lower than at times of higher stream discharge. The same is true for shorter periods in March, April and May, when the flow decreased to the point that the navigation dams were placed in operation to maintain a nine-foot stage.

Peaks of coli-aerogenes index generally occur at or following increases in gage height, increased stream flow, and scour in the river.

These data again suggest the great fluctuation in the quality of the raw water that filtration plants using Ohio River water as a source of supply have to contend with. In the larger plants such as at Cincinnati and Louisville, modern in design and with full-time expert supervision and laboratory control, the plant effluents are believed to have conformed, up to the present time, to the bacteriological standard for a drinking water supply. At Aurora and New Albany, located in zones of heavy pollution below communities of considerable size, with treatment plants which are possibly modern in design and construction but lack full-time expert operating personnel and continuous laboratory control, it is possible that at times, for short periods, the Treasury Department standard for drinking water may not have been met at these plants. Of considerable importance in the case of such plants is the question of the additional sewage load which can be placed upon them before the treated supply will begin to show deterioration to the point where water-borne intestinal disturbances may appear.

Aside from the character of the water after treatment, which is indicated by the chemical and bacterial analysis of the water, there is the question of the effect of soluble substances, reaching the raw water from sewage or from the fermentation of sewage sludge and not removed by filtration, in concentrations which may be sufficient to cause intestinal disturbances, the causative factors not being indicated by the present chemical and bacteriological determinations.

At least one rather extensive outbreak of gastro-enteritis has been recorded in several communities situated on and using the Ohio River as a source of water supply. This outbreak occurred in the fall and winter of 1930-31 at a time of increasing stream flow along the Ohio River after the long period of pool stage in the fall and winter of 1930-31, and raises the question as to whether or not the deposition of sewage solids and their fermentation by bacteria may not be a public health aspect of pollution heretofore not appreciated.

The available data relative to conditions at the various water works intakes, due to the present intensity of pollution in the stream, the difficulties encountered in producing satisfactory supplies, and the additional public health aspect due to the possible effect on health of soluble fermentation products derived from sewage deposits, all suggest that these conditions are encountered at stream discharges considerably in excess of the low summer flows, at a time when the river discharge becomes sufficient to lower the navigation dams and when the velocity becomes great enough to scour material deposited during the lower flows at pool stage.

It is very doubtful, therefore, if increases in low water flow as a result of the flood control program would result in improved conditions in the river water at the water works intakes. On the contrary, moderate increases, if changing present conditions at all, might increase velocities and decrease times of flow from upstream sources of pollution to the extent of increasing pollution at the intakes over that at present. Dilution of the acid drainage in the upper watershed and increased flows should increase the effect of Pittsburgh's sewage at the water treatment plants further downstream.

Flows sufficiently in excess of present low water rates of discharge to prevent sedimentation in the navigation pools, if they could be maintained, but which seems doubtful, would probably result in a greater concentration of pollution below points of population concentration, but with less fluctuations in intensity, which might be more easily removed in water treatment devices than the widely fluctuating degree of pollution at the present time.

(B) - Effect of Decreased Run-Off at Extreme High Water Stages.

At such times as the flood control reservoirs are in operation to store excess run-off to decrease flows in the main channel, the amount of flow in the Ohio River proper will be so great that dilution of the pollution will be the controlling factor and the withdrawal of the relatively small amount of water to storage will in no way affect conditions along the main river, the water of which should show but little effect of the pollution reaching it.